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A
SHORT and GENERAL
ACCOUNT
OF THE MOST
NECESSARY and FUNDAMENTAL
PRINCIPLES
OF
NATURAL PHILOSOPHY:

CONTAINING
MECHANICS, HYDROSTATICS, PNEUMATICS, OPTICS and ASTRONOMY.

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Reviſed, Corrected, and adapted to a COURSE of EXPERIMENTS, perform'd in GLASGOW.

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PREFACE.

BREVITY *(and all the* Perſpicuity *that is conſiſtent with it, and with the Subject that is handled) is one principle Thing I have aimed at in the following Papers. Another Thing I have labour'd hard to accompliſh, is, To give ſufficient and ſatisfactory Proof of every Principle, drawn as much as poſſible from the Reaſon and Nature of Things, induſtriouſly avoiding ſuch Demonſtrations as good Mathematicians only are able to underſtand. Much the greater Part of the Company that is moſt likely to attend our Curſe of Experiments (for whoſe Service and Benefit this ſhort* Treatiſe *is chiefly, or only intended) are ſuch as have had no Opportunity of acquainting themſelves with the very Elements of* Geometry, *much leſs with the more abſtruſe and difficult Parts of Mathematical Learning. And therefore I have made it my Buſſineſs to convince them of the Truth of thoſe Principles, and to help them to a ſufficient Acquaintance with the Nature and Reaſons of all the* Phænomena, *that are accounted for by them, without perplexing or troubling them with any Thing almoſt at all of* Geometry. *And if the following Demonſtrations ſhould not every where be altogether ſo exact and rigo-*

rous, as thoſe that are ſtrictly Geometrical, yet they carry ſo much Evidence in them, (eſpecially when backed with the proper Experiments) as is ſufficient to remove all Manner of Doubt from the Minds of impartial Perſons.

And others perhaps who are better ſkill'd in theſe Matters, and have larger Treatiſes *to conſult, may yet make uſe of this ſhort one, as a Memorandum or Pocket-Companion.*

CHAP.

ERRATA.

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CHAP. I.

Of the PROPERTIES *of MATTER.*

AS it is the Deſign of this Courſe to demonſtrate thoſe Principles by which the Univerſe is govern'd, regulated and continued, and by which the various Appearances of Nature are accounted for, it is neceſſary in the firſt Place to demonſtrate the known Properties of Matter.

By the Word *Matter*, we underſtand every Thing that has Extenſion, and reſiſts the Touch.

Matter is diviſible in Theory *ad infinitum*, as will appear upon the leaſt Conſideration; becauſe we cannot conceive any Particle of it ſo ſmall, but we can imagine it to be divided; for it muſt have an Upper and Under Side, an Eaſt and Weſt Side, *&c.* or elſe it cannot be Matter: But how far Matter can be, or is really divided, is difficult to determine. We have a great many Inſtances of the ſurprizing Smallneſs of ſome Particles.

1*ſt*. If an Once of Silver be gilt with 8 Grains of Gold, it may afterwards be drawn out into a Wire 13000 Feet long, which will be ſo cloſely cover'd over with Gold, that the Silver cannot be ſeen with the beſt Microſcopes. Hence we may find by an eaſy Calculation, that one Grain of Gold is actually divided into 20,000,000 of viſible Parts.

2. Mr. *Lewenhoek* tells us, that in the Milt of a ſingle Cod-fiſh, there are more little Animals than there are

Men upon the Face of the Earth; and from the Data of the Microſcope, we find that one of theſe Animalcula muſt be above 4,000,000 Times leſs than the ſmalleſt viſible Grain of Sand. Now every one muſt have a Head, Heart, Veins, Arteries and Nerves; and how inconceivably ſmall muſt the Particles of their Blood and Animal Spirits be! In ſhort, by Calculations made upon reaſonable Suppoſitions, we find that they are ſo much leſs than a Grain of Sand, as a Grain of Sand is leſs than the Globe of the Earth: And yet theſe are ſo much greater than the Particles of Light, that they would ſeem, in Compariſon of them, to be vaſt Mountains.

The 2*d*. Property of Matter is Paſſiveneſs, or Inactivity, which is that Propenſity it has to continue in the State it is in, whether of Reſt or Motion, till ſome external Force acts upon it. And therefore, if one Body contains 2 or 3 times the Quantity of Matter that another does, it will alſo contain 2 or 3 times the Inactivity; that is, it will require 2 or 3 times the Force to put it into an equal Degree of Motion.

Beſides the forementioned Properties of Matter, there are others, known by the Names of Attraction and Repulſion.

Attraction is that Force by which Bodies are drawn, impell'd, or in ſome Manner made to move towards one another.

And Repulſion that, by which they are made to fly from each other.

Attraction is of two Kinds, 1. Of Coheſion, or that by which the ſmall Parts of Bodies are made to cohere or ſtick together. This is prov'd by a great many Experiments, ſome of which are as follow,

1. If a ſmall Glaſs Tube, open at both Ends be dipt in Water, the Water will riſe up the Tube to a

conſiderable Height above the Level, which muſt be owing to the Attraction of the Particles of Glaſs, for the ſame Thing happens in Vacuo *.

2. Two little Spheres of Mercury brought near each other, will run into one large Sphere.

3. A Piece of Loaf-Sugar will draw up a Fluid, and in the ſame Manner, Sap aſcends in Trees, a Spunge ſucks in water, and the Glands of the Body draw in various Juices from the Blood.

4. Two Pieces of Lead being ſcraped clean, and preſs'd together, will attract each other ſo ſtrongly, as to require 40, 50, 100, or 150 Pounds to pull them aſunder.

Hence it is eaſy to account for the Formation of Bodies; for thoſe Particles which attract each other ſtrongly, and are ſo ſituated as to touch each other in many Points will form hard Bodies; thoſe Particles that touch each other in fewer Points, and perhaps do not attract ſo ſtrongly, will conſtitute a ſofter Body, ſuch as Lead, Peuter, *&c.* thoſe which are perfectly hard, round, ſmooth, and void of Attraction, if any ſuch there be, will conſtitute a perfect Fluid: and ſuch Particles as are not round, but void of Attraction, would form only a Heap of Sand or Duſt.

This Attraction extends but a ſmall Diſtance; for, if the two Spheres of Mercury, mention'd in the ſecond Experiment, be roll'd in Duſt, they will not run together, becauſe, the Particles of Duſt keep the Particles of Mercury out of the Sphere of each others Attraction. Where the Sphere of Attraction ends, a repulſive Force begins; thus Water repels moſt Bodies, till they are wet.

It is upon this Principle, that a ſmall Needle, if dry, ſwims upon Water; and Flies walk upon it, without wetting their Feet.

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* Empty Space, or a Place void of Air.

Attraction of Gravitation, is that by which diſtant Bodies are made to tend towards one another. Of this we have daily Inſtances in the falling of Bodies to the Earth.

Some Attempts have been made towards the diſcovering the Phyſical Cauſes of Gravity; but all ſuch Attempts have hitherto prov'd fruitleſs and vain: And it ſeems beſt to ſuppoſe it to be the immediate Reſult of the Almighty Power or wiſe Appointment of the great Creator of all Things. However, we know by certain Obſervation, that this is a Property belonging to Bodies, and a Property of ſuch an univerſal Extent, as to reach to every One that we know. For that there is no ſuch Thing as poſitive Levity, but that Air, Vapours, and Fumes, have Weight and Gravity in them, is eaſily and certainly prov'd by many Experiments. The true Reaſon why theſe and ſuch like Bodies aſcend, not being any Thing of poſitive Levity, but a lower Degree of Gravity, which obliges them to yield to the ſuperior Force of heavier Bodies; by which Means they are impell'd upwards, and ſo muſt aſcend, whilſt they make Way for other Bodies to deſcend, whoſe Gravity or Tendency downwards, is greater than theirs: Juſt as when any lighter Body or Fluid is immers'd in one that is heavier, the lighter riſes to the upper Part of the Veſſel, whilſt the other deſcends to the lower: And yet the lighter Body is not without it's real or abſolute Gravity.

Gravity, (eſpecially in Fluids) is either *abſolute and true*, or *relative and ſenſible*. The former is the whole Force with which any Body tends downwards towards the Centre of the Earth, and is always exactly proportionable to the Quantity of Matter contain'd in the Body. The other is really no more than the Exceſs of Gravity, by which it has a greater Force or Tendency downwards than the ambient Fluid in which it is plac'd: And therefore, in Vacuo all Bodies deſcend with equal Velocity. If the Receiver be thoroughly exhauſted, a Guinea and Feather fall from any Height in the ſame Space of Time. Gravity is the Force that produces this Motion, and Gravity being proportionable to the Quantity of Matter contain'd in the Body, the Motion that is produced by this Force muſt be ſo too. And the Quantity of Motion being as the Quantity of Matter, if the Velocity be the ſame (as will be ſhewn afterwards) 'tis plain (that ſetting aſide all other Reſiſtance) in order to ſecure the foreſaid Proportion, the Velocity in this Caſe muſt be the ſame in all deſcending Bodies whatever. That is in a Word, if the Velocity be the ſame, the Motion of ſeveral Bodies downwards is as the Quantity of Matter which they contain, and the Gravity is in the very ſame Proportion too, that is, the Effect is as it ſhould be, *viz.* juſt as the Cauſe which produces it.

Gravity at ſeveral Diſtances from the Earth is reciprocally as the Squares of thoſe Diſtances, *viz.* At double the Diſtance, it is 4 times leſs, at 3 the Diſtance, it is 9 Times leſs, *&c.* but where the Difference is ſmall and inconſiderable, it may be look'd upon as always equal and uniform, and as ſuch we muſt at preſent conſider it.

The Velocity which is acquired by Bodies freely deſcending by the Force of their Gravity, muſt be proportionable to the Times of their Deſcent: For ſince the Power of Gravity does not conſiſt in a ſingle Impulſe, or any certain Number of Impulſes, but is always operating, and that in a conſtant uniform Manner; in equal Times it muſt produce equal Effects; that is, in a double or treble Time, a double or treble Celerity, and ſo on. Or if you imagine the

Power of Gravity to exert itſelf by an infinite Number of repeated Impulſes; then if one Impulſe, in one Moment of Time, give the Body a certain Degree of Celerity, a ſecond Impulſe, in a ſecond Moment of Time, will give it another: And ſo this Force acting perpetually upon the Body, muſt accelerate it proportionably to the Number of the foreſaid Impulſes; that is, proportionably to the Time of Deſcent.

The more ſwiftly any Body moves, and the longer alſo it continues its Motion, the greater muſt the Space be which it deſcribes or runs over: So that the Space is always proportionable to the Product ariſing from the Time and Velocity multiply'd into each other; but the Velocity of deſcending Bodies being as the Time of their Deſcent, the Space deſcribed will be as the Time multiplied into the Time, or as the Square of the Time.

The ſame Things may be pretty eaſily conceiv'd in the following Manner.

If a Body departing from Reſt move through any certain Space, in a given Time, with a Celerity, conſtantly and gradually increaſing, 'tis plain that with half the greateſt Celerity (conſtant and unalter'd) it wou'd have mov'd through the very ſame Space in the very ſame Time; this being the true Mean, and the Defect on the one Hand being juſt compenſated by the Exceſs on the other. From hence it is evident, that if the Body ſhould continue to move for the ſame given Time, with the greateſt acquired Celerity, it muſt run over double the Space. For in a given Time, the Space muſt always be proportionable to the Celerity; and in this Caſe, the one conſtant Celerity would be juſt the Double of the other.

Suppoſe then a Body which was at Reſt, does begin to move with a Motion conſtantly and uniformly accelerated, and that with ſuch a Motion, whoſe Celerity is conſtantly and gradually increaſing, it runs over a Mile in a Minute; at the End of this Space, it will have acquired ſuch a Degree of Celerity, as is ſufficient to carry it two Miles in one Minute more, tho' it ſhou'd receive no new Impulſes, no farther Impreſſion from the Cauſe or Power by which its Motion had been accelerated: But if the ſame accelerating Cauſe continue ſtill to act upon the Body, and that in the ſame conſtant uniform Manner, it muſt in equal Times produce equal Effects, *i. e.* carry it a Mile in a Minute: So that ſuch a Body would in the ſecond Minute paſs over two Miles, by Vertue of the Celerity acquired in its Motion the firſt, and one Mile more upon the Account of the new Impreſſion from the Force that conſtantly accelerates its Motion, that is, three Miles in all: So that in two Minutes, the Body muſt have mov'd four Miles, *viz.* one the firſt Minute, and three the ſecond. At the End of this Time and Space, it has again acquired ſuch a greater Degree of Celerity, as is ſufficient to carry it eight Miles in two Minutes (*i. e.* double the Space in the ſame Time) or four in one, tho' the accelerating Force ſhould act upon it no more: But if this Power, whatever it be, continues ſtill to operate or exert it ſelf in an uniform Manner, it will again in an equal Time produce an equal Effect, and ſo in this Minute too carry the ſame Body a Mile further on, thus cauſing it to move five Miles the third Minute. For the new Impulſes of the accelerating Cauſe don't at all deſtroy or diminiſh the former Celerity already acquired: And therefore the Celerity that is already acquired, and the Celerity that is conſtantly acquiring, will both of them have their compleat entire Effect. So that upon the whole, it appears, that this Body would move one Mile the firſt Minute, three the ſecond, five the third:

And if you carry on the ſame Sort of Proof, it would be ſeven for the fourth Minute, nine for the fifth, and ſo on.

From hence it is plain, that the Spaces deſcribed in ſucceſſive equal Parts of Time, by an uniformly accelerated Motion (ſuch as is that of a heavy Body freely deſcending) are always as the odd Numbers, 1, 3, 5, 7, 9, *&c.* And conſequently the whole Spaces are as the Squares of the Times, or of the Velocities (the Times and Velocities being proportionable one to another.) For the continued Addition of the odd Numbers yields the Squares of all Numbers from Unity upward. Thus one is the firſt odd Number, and the Square of one, is one; three is the ſecond odd Number, and this added to one makes four the Square of two. And again five is the third odd Number which added to four makes nine the Square of three, and ſo on *ad infinitum.* Since therefore the Times (and conſequently the Velocities) proceed evenly and conſtantly as one, two, three, four, *&c.* but the Spaces deſcribed in each equal Time are as one, three, five, ſeven, *&c.*

Hence 'tis evident, that the Space deſcrib'd

In 1 Min. will be 1 = Sq. of 1
In 2 Min. 1 + 3 = 4 = Sq. of 2
In 3 Min. 1 + 3 + 5 = 9 = Sq. of 3
In 4 Min. 1 + 3 + 5 + 7 = 16 = Sq. of 4 *&c.*

The Spaces being always as the Squares of the Times: Or to make it ſtill plainer, we know that a heavy Body will fall 16 Feet and 1 Inch, in a Second of Time; in 2 Seconds, it will therefore deſcend 4 Times 16, or 64 Feet and 4 Inches; in 3 Seconds, it will fall 9 Times 16 Feet and 9 Inches, *&c.*

Hence we can eaſily find the Depth of a Well or Coal-pit, by obſerving the Time a Body is in falling to the Bottom.

As heavy Bodies are uniformly accelerated in their Deſcent, ſo it is plain, that in their Aſcent they muſt be retarded in the ſame Manner: Therefore, the Velocity which a Body acquires by falling, is juſt ſufficient to carry it up again to the ſame Height, from whence it had fallen; Allowance being made for the Reſiſtance of the Air, or other Medium, in which the Body is mov'd.

The *Centre of Gravity* is that Point of any Body, in which the whole Force of its Gravity is united and centred: So that whatever ſuſtains that Point, bears the whole Weight of the Body, and the Body being ſupported or ſuſpended by it, all the Parts of it will be in a perfect Equilibrium.

The Imaginary Line drawn from the Centre of Gravity, to the Centre of the Earth, according to which all heavy Bodies deſcend (if no way obſtructed) is call'd, *The Line of Direction*.

From the Definition of the Centre of Gravity, it eaſily follows, that according as the Centre of Gravity aſcends or deſcends, we muſt look upon the whole Body to do ſo: Becauſe the whole Weight or Force unites in that Point. And becauſe it is contrary to the Nature of heavy Bodies (and conſequently of the Centre of Gravity) to aſcend of their own accord, or not to deſcend when permitted to do ſo: Hence it is, that Bodies ſtand upon their Baſes, when they cannot change their Poſition, or cannot tumble or fall; but the Centre of Gravity muſt aſcend and be really higher than it was before. Whilſt on the other Hand they certainly tumble or fall, if in overturning the Body the Centre of Gravity deſcends, and becomes really lower. Now this is the Reaſon why, when the Line of Direction paſſes through the Baſe of any Body, it muſt ſtand upon its Bottom; but when the Line falls out of the Baſe, it muſt certainly tumble or fall: For this Line does like a Rope, tye it faſt as it were to the Ground in the one Caſe, and pull it over in the other.

Since then the ſtanding of a Body upon its own Baſe, depends upon the Line of Direction's falling within it; 'tis plain that the larger the Baſe, and the nearer the Line of Direction is to its Middle or Centre, the more firmly the Body muſt ſtand: But on the other Hand, the leſs the Baſe, and the nearer the Line of Direction to the Side of it, the more eaſily may the Body be overthrown. A leſs Change of Poſition being ſufficient to remove the Line of Direction out of the Baſe in the one Caſe, than in the other. And from hence it is that a Sphere does ſo eaſily roll on a Plane, and that it is ſo difficult, if poſſible, to make thoſe Things that are ſharp pointed to ſtand upright. And from what has been ſaid, it clearly appears, that if the Plane upon which the heavy Body is placed, be inclin'd, the Body will ſlide down it, while the Line of Direction falls within its Baſe, but will tumble or roll when without it.

This Law of *Statics* we naturally obſerve (and ſo do even the irrational Creatures) to prevent our falling or tumbling. For when the Line of Direction is within the Baſe of our Feet, we ſtand, and moſt firmly when it is juſt in the Middle: But when it is out of that Baſe, we immediatly fall. And it is pleaſing and ſurprizing to reflect upon the various unobſerved unthought of Methods and Poſtures we uſe to retain this Poſition, or to recover it when we have loſt, or are in Danger of loſing it. For this Reaſon do we bend forward when we riſe from our Seat, or go up any Stairs. For this Reaſon does a Man lean forward or backward as he carries his Burden behind or before; or to the Right-hand or Left, as he carries it on the oppoſite Side. And a thouſand Inſtances more of the like Nature, might be very eaſily added.

Beſides the univerſal Properties before explained, there are Bodies that have Properties peculiar to themſelves, ſuch as the Loadſtone in which the moſt remarkable are, 1. It attracts Iron and Steel only. 2. It turns one of its Sides to the North, and another to the South, when left at Liberty. 3. It communicates all its Properties to a Piece of Steel when rubb'd upon it without loſing any itſelf.

For, a long Piece of Steel rubbed upon it, and then nicely ſuſpended upon the Point of a Pin, will turn one End to the North, and the other to the South, except a little Variation which is different, at different Times and Places. In ſome Places, the Variation is 10, 20, or 30 Degrees; in others, 40, 50 or 60; and at *London* in the Year 1580, the Variation was, 11° 17′ Eaſtward; in 1663 it was very little, either one Way or other; but in the Year 1734, it was 12 or 13 Degrees Weſtward.

Several other Bodies (particularly Amber, Glaſs, Jet, Sealing-wax, Agate, and almoſt all precious Stones) have a peculiar Property of attracting and repelling light Bodies, when heated by rubbing. This is call'd *Electrical Attraction.*

The chief Things to be obſerv'd are, 1. If a Glaſs Tube (about 1 Inch and a half Diameter, and 2 or 3 Foot long) be heated by rubbing, it will alternately attract and repel all light Bodies, at the Diſtance of 10 or 15 Inches. 2. It does not attract by being heated without rubbing. 3. Any light Body being once repell'd by the Tube, will never be attracted again till it has touch'd ſome other Body. 4. If the Tube be rubb'd with a moiſt Hand, or any Thing that is wet, it totally deſtroys the Electricity. 5. Any Body, except Air, being interpos'd, ſtops the Electricity. 6. It attracts ſtronger when rubb'd over with Bees-wax, and then with a dry wollen Cloth. 7. When it is well rubb'd, if a Finger be mov'd by it at the Diſtance of about half an Inch, the Effuvia will ſnap againſt the Finger, and make a little crackling Noiſe; and being perform'd in a dark Place, there will appear a little Flaſh of Light.

All Bodies are affected ſome Way or other by heat; thus, all Metals are expanded, or encreas'd in Length, Breadth, and Thickneſs thereby.

The Proportion of the Expanſion of ſeveral Metals, according to the beſt Experiments and Obſervations, I have been able to make, is nearly thus; Iron 3. Glaſs 3. Steel 4. Copper 4 and one eighth. Braſs 5. Tin 6. Lead 6 and one eighth.

An Iron Rod 3 Feet long, is about one 70th Part of an Inch longer in Summer than Winter.

CHAP. II.

Sir ISAAC NEWTON's *general* AXIOMS, *or* LAWS *of* MOTION, *chiefly taken from his* Principia Mathematica.

AXIOM, 1ſt. *Every Body perſeveres in its preſent State either of Reſt or direct and uniform Motion, till it be conſtrain'd to alter it by a Force impreſt upon it ſome Way or other.* A Body at Reſt would remain ſo for ever by its own *Inactivity*; and a Body in Motion even for the ſame Reaſon would move for ever in the ſame Direction (and ſo its Motion always be *Rectilinear*) and with the ſame Degree of Celerity, if ſome Force or other made no Alteration.

Axiom 2d. *The Change produc'd is proportionable to the Force that is impreſt, and (in the Caſe of Motion) according to the Line of Direction in which that Force is impreſt.* The Effects of natural Cauſes in general are equal or proportionable to the Force and Power of theſe Cauſes.

Axiom 3d. *Action and Reaction are always equal and contrary one to another.* Whatever preſſes or draws another Thing is equally preſt or drawn by it, but in the contrary Way. If a Horſe draws a Stone faſtned to a Rope, the Horſe is equally drawn back towards the Stone. For the Rope being equally ſtretch'd on both Sides, will by its Endeavour to relax itſelf, equally draw the Horſe towards the Stone, and the Stone towards the Horſe. If you preſs upon the Table with your Hand, the Reſiſtance or Reaction is equal to the Preſſure, and your Hand is as much preſt as the Table. If one Body ſtrike upon another, and thereby produce any Change in its Motion, it does by the Reſiſtance or Reaction of the other Body undergo a like Change itſelf, tho' to the contrary Part; and always loſes as much Motion as it produces, imparts, or communicates.

By theſe Laws, it will be eaſy to prove, that a Body will deſcribe the Diagonal of a Parallelogram, by two Forces conjoin'd, in the ſame Time, that it would deſcribe the Sides, by each Force ſeparately. This is that famous Propoſition of Sir *Iſaac Newton*, upon which, his whole Syſtem depends.

igure 1. That it may be more eaſily underſtood, Suppoſe the Body A to repreſent a Ship at Sea, and that it is drove by the Wind in the Direction of the Line A B with ſuch a Force, as would carry it uniformly 8 Miles in an Hour, from A to B. Then ſuppoſe a Stream or Current of Water running in the Direction A D, with ſuch Force as would carry the Ship 4 Miles in an Hour, from A to D; by theſe two Forces acting together, the Ship will deſcribe the Diagonal A C, and at the End of an Hour it will be found at the Point C.

igure 1. and 2. For, the Force A B will not hinder the Body's approaching the Line D C, drawn parallel to it, neither will the Force A D, hinder the Body from approaching the Line B C, therefore the Body will be found at the End of the given Time, in the Point C.

If both the Forces act upon a Body, in ſuch a Manner, as to cauſe it move uniformly, the Diagonal deſcrib'd will be a right Line; but if one of the Forces acts in ſuch a Manner, as to make the Body move faſter and faſter, as it goes forward, then the Line deſcrib'd will be a Curve; thus ſuppoſe one Force to drive a Body in the Direction A F, ſo as to make it move thro' the equal Spaces A B, B C, C D, *&c.* in equal Times; then ſuppoſe another Force to act in the Direction A X, in ſuch a Manner, as to make it deſcribe the unequal Spaces, *A m*, *m n*, *n w*, *&c.* in equal Times; theſe two Forces will make the Body deſcribe the Curve *A p q r ſ*. If the Spaces *A m*, *mn*, *nw*, *&c.* be the Spaces thro' which a Body falls, by the Force of Gravity, in equal Times, the Curve *A p q r ſ*, will be the Curve that is deſcrib'd by a Projectile, as a Ball from a Gun, and is call'd a Parabola. For, ſuppoſe in the ſame Time that the Force of the Powder drives the Ball from A to B, that Gravity would make it fall from *A* to *m*, the Body in that Time will deſcribe the Diagonal *A p* by the foregoing Rule: But in double the Time, Gravity will make a Body deſcend 4 times as far, that is, to *n*, and the Force of the Powder will drive twice as far, *viz.* to *c*; ſo, that at the End of the 2*d* Part of Time, the Body will be found at *q*, and ſo for the like Reaſon, at the End of the 3*d* Part of Time, the Body will be found at *r*; at the End of the 4*th* at *ſ*, *&c.*

Thus having explain'd the Motion of Bodies, by different Forces, it remains only to ſay a Word or two concerning abſolute and relative Motions. Abſolute Motion, is when one Body moves with Reſpect to another that is at Reſt; So relative Motion, is the Motion of a Body with Reſpect to another, that moves at the ſame Time.

Nothing is more obvious and plain, than that ſeveral Bodies may retain the ſame Poſition with Reſpect to each other, and ſo be relatively at Reſt; whilſt at the ſame Time, abſolutely ſpeaking, they are all of them mov'd: As when a Ship is under Sail, the ſeveral Parts of her Loading will be at Reſt with Reſpect to one another, yet, they are all really in Motion along with the Ship. Yea, we cannot poſſibly be ſure, that any one Thing we know of, is abſolutely ſpeaking at Reſt, for there may ſtill be ſome Body vaſtly diſtant, but truly quieſcent, with Reſpect to which, any Body we imagine to be at Reſt, does really change its Poſition.

When ever the whole is abſolutely mov'd, the Parts tho' relatively at Reſt, do each of them partake of this abſolute Motion: And by Reaſon of this any Part has a conſtant Diſpoſition and a ſufficient Force to proceed with the ſame Degree of Celerity, tho' it ſhould be ſeparated from the Reſt, or tho' the Reſt ſhould ſtop on a ſudden, and ceaſe from their Motion. And this appears more eſpecially in a circular Motion. If a circular Plane, or a ſpherical Body, move round its Axis, tho' the Parts of it may retain the ſame Poſition with Reſpect to each other, yet by partaking of the abſolute Motion, there is in each of them a perpetual Diſpoſition or Conatus to recede from the Centre or Axis. And the greater the Celerity, the ſtronger is this Attempt or Conatus; but if a Body moves in a right Line, another Body will move upon it in the ſame Manner as tho' the firſt Body was at reſt; thus all Motions upon the Deck of a Ship under Sail are the ſame, and all Bodies hang perpendicular in the ſame Manner, as tho' the Ship was at Reſt.

And hence it is, that the Earth moving at the Rate of 58,000 Miles an Hour, all Bodies on the Surface of the Earth move with Reſpect to it, almoſt in the ſame Manner, as tho' it was at Reſt, for during the Time a Projectile moves in the Air, the Earth moves ſo nearly in a right Line, that the Difference is inconſiderable.

CHAP.

CHAP. III.

MECHANICS;

OR,

The METHOD *of computing the* FORCE *of all* SORTS *of* ENGINES.

IF we conſider Bodies in motion, and would compare them together, we may do this either with Reſpect to the Quantity of Matter which they contain, or with Reſpect to the Celerity with which they are mov'd. The greater and heavier any Body is (*i. e.* the greater Quantity of Matter it contains) the greater Power it muſt have to produce any Effect, or to conquer any Reſiſtance, and the greater Force is required to ſtop or deſtroy the Motion of it: And again, the more ſwiftly it moves, the greater alſo its Force. So that the whole Force or Quantity of Motion or Power of a moving Body (which is call'd its *Momentum*) is the Reſult of the Quantity of Matter contain'd in that Body, when multiplied into the Velocity with which it is mov'd. And if theſe Products of any two moving Bodies be equal, their Momentum or entire Force muſt be ſo too. Upon this eaſy and obvious Principle, depends the whole of Mechanics. For in all Engines whatever, the Greatneſs of the Weight or Reſiſtance, is compenſated by the Celerity of the Power that is to raiſe or remove it. And in computing the Force of any Machine, do but enquire how much ſwifter the Power moves than the Weight or Reſiſtance (*i. e.* how much farther in the ſame Space of Time) and juſt ſo much more muſt the Power be increaſed by the Help of the Engine

Thus in the Lever, at the greater Diſtance of the Fulcrum, the Power is applied, ſo much the greater Advantage it has. Thus it is in a Balance; the ſame Weight, apply'd at double or treble, *&c.* the Diſtance from theCentre of Motion, has double or treble Force; becauſe whenever the Balance is mov'd, the more diſtant Weight muſt move with the greater Celerity. But then this Diſtance muſt be ſtraight and direct; the Crookedneſs of the Line does not really increaſe the Diſtance, and conſequently not the Velocity, and therefore can contribute nothing at all to the Force.

The direct Diſtance therefore, and ſo the Velocity or Force is determin'd by a Perpendicular let fall upon the Brachium of the Balance when drawn out or continued (if needful) in a right Line: Or, it is the perpendicular Diſtance of the Line of Direction of the Power from the Centre of Motion.

Levers are reckon'd of three Kinds according to the Poſition of the Power, with Reſpect to the Weight and the Fulcrum: For either (as uſual) the Fulcrum is between the Weight and the Power; or elſe the Weight is between the Power and the Fulcrum; or laſtly, the Power is between the Weight and the Fulcrum.

To thoſe of the firſt Sort belong the Iron Levers that are commonly uſed for raiſing of Stones, or the like. Sciſſers alſo, Pinchers, Snuffers, and the like, are made up of two ſuch Levers acting contray Ways, or with oppoſite Directions one to another.

To the ſecond Sort may be reduced Oars, ſuch cutting Knives as are fixed at one End, and the like.

To the third Sort are generally refer'd the Bones of a Man's Arm or Leg; for, when we lift a Weight by the Hand, the Muſcle that is exerted to raiſe that Weight is fix'd to the Bone, about one 10*th* Part as far from the Elbow as the Hand is, and the Elbow being the Centre round which the Arm turns, the Muſcle muſt, therefore, exert a Force 10 times greater than the Weight rais'd.

Hence it will be eaſy to calculate the Strength of the Muſcles in any Part of the Body, by trying how much they can lift at any Diſtance from the Centre.

If two Men carry a Burden between them, and the Load be placed upon a Pole or a Stick at unequal Diſtances from them; it is certain, and well known, that the nearer either of them is to the Burden, the greater Share muſt he bear of it. This is eaſily accounted for, from the Nature of the Centre of Gravity. For as one who is placed directly under the Centre of Gravity, or in this Line of Direction, muſt ſuſtain the whole Weight; ſo, the nearer he is to it, the more he muſt bear. Or the Stick may be imagin'd to be a Lever of the ſecond Kind, and each Man's Shoulder the Fulcrum with Reſpect to the other; and then 'tis plain, that the nearer the Weight is to the Fulcrum, and the farther the Power is from it, the greater is the Advantage. This is applicable too to the Caſe of two Horſes of unequal Strength, to be ſo yoaked, as that each of them may draw a Part proportionable to his Strength; which is done by dividing the Beam, ſo as that the Point of Traction be as much nearer to the ſtronger Horſe, as his Strength is greater than that of the other.

Thus any thing is moſt difficultly lifted at Arms-end; becauſe then, the Shoulder, being the Fulcrum, the Weight is at a greater Diſtance from it, than if the Fulcrum was either at the Wreiſt, or the Elbow. And a Stick is more difficultly raiſed when held out at length, than when taken hold of by the Middle; becauſe in the former Caſe, the Centre of Gravity of the Stick (or if you will, the Centre of Percuſſion) is further from the Fulcrum, than in the latter.

The Balance differs not much from the Lever, the Centre of Motion being looked upon as the Fulcrum. And the further the Weight is placed from this Centre, the greater muſt be its Celerity: So that the Motion is equally augmented, either by increaſing the Weight, or increaſing the Diſtance.

Where the Momentum, or the Sum of the Momenta is equal on both Sides, then and then only the Balance muſt be in Equilibrio. So that it is eaſy to conceive how one and the ſame Weight (as in the Steelyard) may, by being ſuſpended at different Diſtances, balance different Weights, that are always placed at one and the ſame Diſtance from the Centre of Motion. Nor will any, who conſiders the Matter, need to be told that a Balance cannot be juſt or exact, except its two Arms be perfectly equal one to the other. A Balance that has Arms of an unequal Length, commonly bears the Name of a *deceitful Balance.*

N. B. Tho' the applying the Weight at different Diſtances from the Centre of Motion, makes ſo great an Alteration in its Force or Momentum; yet its hanging at different Diſtances from the Point of Suſpenſion, makes none at all, if Allowance be made for the Weight of the String.

The Axis in Peritrochio, or Axle in the Wheel, is a very plain and ſimple Machine, and the Advantage that redounds to the Power by the Uſe of it, is very eaſy to be computed from the general Principle already laid down. For the Power is ſo much increaſed, as the Circumference of the Wheel is greater than that of the Axis. The former being the Velocity of the Power, or the Space deſcrib'd in the ſame Time, that the Reſiſtance or Weight runs o'er the latter.

The Pully is another Mechanical Power, the Force of which is alſo eaſily computed from the very ſame general Principle. For do but carefully obſerve how many Inches (for Inſtance) the Power muſt deſcend in the ſame Time that the Weight aſcends one, and juſt ſo many Times muſt the Power be increaſed by this Engine: And that you'll eaſily obſerve is juſt ſo many Times as is the Number of Strings, beſide that to which the Power itſelf is appply'd. Thus in a ſingle Pully the Power is neither increaſed nor diminiſh'd, there being only two Strings in all, to one of which the Power itſelf is apply'd. In a double Pully, the Strings being three in all, you have double the Force, and ſo on.

The very ſame general Rule is eaſily applicable to the two remaining mechanical Powers, *viz.* the Wedge, and the Screw. For, in the former Caſe 'tis plain, that the Power proceeds according to the Length, but the Reſiſtance is removed only according to the Breadth of the Wedge: And therefore, as much as the Length exceeds the Breadth, or (as they ſometimes call it) the Thickneſs of the Wedge, ſo much is the Power heightened by the Uſe of this Inſtrument. And to this may be reduced all Sorts of Pointed, or Edge-Tools.

And as for the Screw, 'tis evident, that the Power muſt move round the Cylinder, before the Weight or Reſiſtance aſcends from one Spiral Winding to the other,

other. As much, therefore, as the Circumference of the Cylinder is greater than the Diſtance or Interval between the Spiral Lines, ſo much may the Power be leſs than the Weight or Reſiſtance, and yet be ſufficient to balance it. The greater therefore the Circumference, and the ſmaller the Diſtance of the Helixes or Spirals, the greater is the Force of the Screw. This Inſtrument, beſides the Advantage proper to itſelf, has generally upon the Account of the Handle, the Benefit too of the Axis in Peritrochio.

In a Word, the greater the Celerity of the Power, the greater its Force, or as it is vulgarly expreſt, with Reſpect to the Lever, (to which the other Mechanical Powers are reducible) the greater the Purchaſe, the greater the Power.

And in an Engine compounded of ſeveral of theſe Mechanical Powers, 'tis a Matter of no great Difficulty to compute the Force of the whole, by reckoning the Force of every Part, or by tracing from the Beginning to the End, the Superior Degree of Celerity, with which the Power moves when compar'd with that of the Weight or Reſiſtance, that is to be raiſed or overcome.

Only it is to be obſerved, that no Engine can be made ſo perfectly ſmooth or exact, but ſome Part of its Force will be loſt, by what they call *Friction*, or the rubbing of the Parts againſt one another, or ſome other Obſtacles of the like Nature.

A *Pendulum* is a Weight hanging at the End of a String, by whoſe *Vibrations*, or Swings to and fro, the Parts of Time may be moſt exactly and moſt conveniently meaſur'd.

If a Pendulum ſwing into very ſmall Arcs of a Circle, the times of the Swings or Vibrations (whether greater or ſmaller) ſhall be all of them equal. 'Tis ſtrictly true of the Cycloid only, or of the Chords of a Circle, that a heavy Body deſcribes or deſcends thro' any or all of them in equal Times: And where the Arcs are ſo ſmall as nearly to coincide with the Chords, the ſame thing muſt be alſo true of them without any ſenſible Difference. And it is eaſy to conceive in the general, that a larger Space may be deſcrib'd in the ſame Time as a leſſer; if the Celerity be proportionably greater, as it is in this Caſe.

The Solution of all the common Problems relating to Pendulums, depends upon this general Principle, *viz.* that the Squares of the Times in which the different Pendulums perform their reſpective Vibrations, are directly as the Lengths of theſe Pendulums, (reckoning from the Centre of *Suſpenſion*, i. e. The Point upon which the Pendulum ſwings, to the Centre of *Oſcillation*, i. e. In this Caſe to the Centre of the Ball or Bob.)

'Tis agreed, that in our Latitude, a Pendulum, whoſe Length is 39. 2 Inches, will perform each Vibration exactly in a Second of Time. And this being fix'd and determined, if the Length of any other Pendulum be given, 'tis eaſy to diſcover in what Time it will perform its Vibrations; or if the Time be given, 'tis eaſy to find the Length of the Pendulum from the general Principle that was juſt now laid down; only it muſt be conſider'd, that the longer the Space is in which any Vibration is perform'd, the fewer ſuch Vibrations there can be in any certain determinate Time, as in an Hour or a Minute; ſo that when you work by the Number of Vibrations perform'd in a Minute, in order to find out the Length of the Pendulum, the Proportion muſt be reciprocal, *i. e.* the fewer the Vibrations, the longer the Pendulum. Suppoſe a Pendulum vibrates 30 times in a Minute, what is its Length? Say, as the Square of

30 is to the Square of 60, (the Number of Vibrations perform'd in a Minute by a Pendulum that ſwings Seconds) ſo is 39, 2 (the Length of ſuch a Pendulum) to a fourth Number, which is the length that is ſought: Or divide this Number 141120 (*viz.* 60 x 60 x 39, 2) by the Square of the Number of Vibrations in a Minute, and the Quotient will be the Length of the Pendulum in Inches.

The Centre of Oſcillation is a Point in which if all the Matter of the Pendulum was collected, it would vibrate in the ſame Time; from this Point to the Centre of Suſpenſion, the Length of the Pendulum is generally meaſured.

As all Metals expand with Heat, conſequently common Pendulums made with Metals will be liable to Alteration by Heat, but a Pendulum may be made that will correct that Irregularity in the following Manner.

Figure 4. Let the Wire or Rod C W be Braſs, and F B Iron, fix'd together at F. Make the Length C B to that of C F, as 10 to 15; and the Length C B, to that of C W, as 10 to 24,142. Let it ſwing upon Point C, and make the Weight of the Rods C W, together with the Weight W, equal to the Weight of the Rod C B, together with the Weight B *.

CHAP.

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* As the Demonſtration of what is here aſſerted is not to be found in any other Place, I ſhall give it here as follows.

Let the Weight B be imagin'd to be at b, as much below the Centre C as it really is above; and call C b or C B, b; and C W, x; then find the Diſtance of the Centre of Oſcillation from C, the Point of Suſpenſion; that is, the Length of a ſimple Pendulum which will vibrate in the ſame Time with this compound one; which by known Rules will be $\frac{xx + bb}{x + b}$ but if the Weight b, be imagin'd to move towards C, the Quantity $b = Cb$, will decreaſe till b comes to C, where it will vaniſh; and while it moves forward in the

CHAP. IV.

HYDROSTATICS;

OR,

The PROPERTIES *of* FLUIDS *in General.*

I. *HYDROSTATICS*, when firſt invented by *Archimedes*, conſiſted only in the Art of weighing Bodies in Water; but, as ſince improv'd, comprehends the Nature and Properties of Fluids in general.

II. A

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the Direction C B, it will be negative; therefore, in the preſent Caſe, where the weight B is above the Centre, the Quantity b = C B, muſt be negative; and in the foregoing Theorem, all the odd Powers thereof muſt be chang'd, then we have $\frac{xx+bb}{x-b}$ the Length of a ſimple Pendulum, which will vibrate in the ſame Time with this compound one, abſtracting from the Weights of the Wires. Now, as the Lengths F B, F C are inverſely as their Expanſions; the Quantity of C B, b, will be invariable; tho' the Wires F C and F B ſhould expand or contract; and as it is to vibrate always in the ſame Time, the Fluxion of the ſimple Pendulum $\frac{xx+bb}{x-b}$ muſt be equal 0, therefore $xx\dot{x} - 2x\dot{x}b - \dot{x}bb = 0$; Dividing by x, and putting b = 10, we find x = 24,142; therefore C B is to C W as 10 to 24,142.

This is the *Ratio* of the Lengths when the Vibrations are leaſt liable to Alteration, and tho' there be no more than two different Degrees of Heat, in which the Vibrations will be mathematically the ſame, yet the Alteration will be inconſiderable, as may be eaſily tried by Calculation.

To find how many Vibrations it will make in a Minute; multiply the Difference of the Lengths of C W and C B by 141120; divide the Product by the Sum of the Squares of the Lengths, and extract the Square Root of the Quotient.

II. A perfect Fluid * is a Body that yields to the leaſt Preſſure, or Difference of Preſſures, and hath its Parts mov'd eaſily one among another.

III. The conſtituent Particles of a Fluid muſt be ſmall, becauſe they cannot be diſcern'd with the beſt Microſcope; they muſt be round and ſmooth, becauſe they move ſo eaſily one among another; and hard, becauſe no Fluid except the Air or Steam, is compreſſible, or can be preſs'd into a leſs Space, than it naturally poſſeſſes.

Corol. Hence any Particle or Quantity of a Fluid can never be at Reſt, till it is equally preſs'd every Way.

IV. Fluids preſs with a Force that is proportionable to their perpendicular Height; for, ſuppoſe the Fluid in the Veſſel A F be divided into ſeveral Parts A B C D, *&c.* the loweſt Part F muſt be preſs'd by all the Parts that are above it, and ſo the Part E or D will be preſs'd by all the Parts that are above; and therefore, any other Part of the Fluid, or any Body put therein, will be preſs'd with a greater or leſs Force, according to its Diſtance from the Surface. Thus a Bottle being cloſe cork'd up, and ſunk a great Depth into the Sea, will either be preſs'd together, or have the Cork thruſt into it. Fig. 5.

V. Fluids will always move towards that Side where they are leaſt preſs'd, as is evident from the Definition of a Fluid; and therefore, they are ſaid to preſs ſide-ways. Thus, if a Hole be made in the Side of a Veſſel, a Fluid put therein will ruſh out at the Hole, and this Side-way Preſſure is equal to the perpendicular or downward Preſſure, for it will run out with equal Velocity whether the Hole be made at the Side of the Veſſel (at *ſ*) or at the Bottom (as at *b*) provided Fig. 5 the Diſtance from the Surface of the Fluid be the ſame: And in like Manner, a Fluid preſſes upward with an equal Force; for if a Tube as *n* be turn'd upward, Water will ſpout from it almoſt as high as the Surface thereof in the Veſſel; but a little Allowance muſt be made for the Reſiſtance of the Air, and the Friction of the Water in the Pipe.

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* We do not know that there is really any ſuch a Thing in Nature as a perfect Fluid, but thoſe Bodies which come neareſt thereto, are, Water, Mercury, *&c.* and theſe, or ſuch like Bodies, we ſhall hereafter call Fluids, becauſe they do not ſenſibly differ from perfect Fluids.

This may be farther demonſtrated thus. Take a ſmooth Weight, as a Piece of Lead, and fitting it to the End of a Tube, with a wet Leather between them, hold the Weight by a String to the End of the Tube, and put it under Water about 12 times its own Thickneſs or more, and letting go the String, the Preſſure of the Water upward againſt the Weight will ſupport it.

For the ſame Reaſon, if a Piece of Paper be put over the Mouth of a Glaſs full of Water, and the Glaſs carefully turn'd with the Mouth downward, the Water will remain ſuſpended in the Glaſs by the Preſſure of the Atmoſphere.

The ſame Thing may be demonſtrated by other Experiments.

VI. The Preſure of a Fluid againſt the Bottom, or Side of a Veſſel, or upon any Body put therein, is as the perpendicular Height only, and not always as the Quantity of the Fluid, as may be demonſtrated thus;

Let Water be pour'd into the Veſſel A B C, and Fig. 6. it will riſe to an equal Height in both Legs; and therefore, the Particles of Water at B (by Def. of a Fluid) are equally preſs'd from both Sides; that is, the Water in the ſmall Tube A B, preſſes as much as that in C B, and conſequently the Preſſure is not as the Quantity of the Fluid, but as the perpendicular Height.

Cor. 1 Hence ariſes this Paradox, that a ſmall Quantity of a Fluid may be made to preſs as much as any other Quantity how great ſoever; for if the Tube C B be ſuppos'd to be increas'd in Diameter, and the Tube A B decreas'd till the Quantity of the Fluid contain'd in each be in any ratio whatſoever, provided the Heights remain the ſame, the Preſſures will be equal.

Fig. 7. *Cor.* 2. If two Veſſels A and B, of equal Baſes and Altitudes, be filled with Water, the Bottom of each will be equally preſs'd. And if a Hole be made, in the Bottom of each Veſſel the Water will run as faſt out of one as the other, ſo long as they are all kept fill'd to the ſame Height.

Cor. 3. The Preſſure of the Sea, againſt its Banks is not greater than that of a ſmall River or Pond of the ſame Depth, abſtracting from the Force of the Waves, and he Difference of Weight between Salt, and Freſh Water.

VII. When we ſay, that Fluids preſs in Proportion to their Altitudes, we mean, upon any equal Part of the Bottom or Sides of a Veſſel. But, if the Bottom of one Veſſel be greater than that of another, the whole Preſſure upon it is as the Area of the Bottom, or as the Square of the like Sides or Diameters.

Tho' the Preſſure of a Fluid againſt the Bottom or Sides of the Veſſels A and B, *Fig*. 7. be equal, yet the abſolute Weight of the Fluid muſt be as the Quantity thereof contain'd in each Veſſel.

VIII. The Velocity with which a Fluid ſpouts out at the Bottom or Side of a Veſſel is, as the Square Root of the Depth: For, in order to make double the Quantity of the Fluid run out with double the Velocity, it muſt require 4 times the Preſſure, and therefore 4 times the Depth: And for the ſame Reaſon, 3 times the Quantity running out with 3 times the Velocity, will require 9 times the Preſſure, or 9 times the Depth, &c.

CHHP.

CHAP. V.

Of the Specific GRAVITY *of* BODIES.

Def. 1. THE Specific Gravities of Bodies are their Weights, Bulk for Bulk; thus a Body is ſaid to have 2 or 3 times the Specific Gravity, when it contains 2 or 3 times as much Weight or Matter in the ſame Space.

Def. 2. The relative Weight or Gravity of a Body, is the Exceſs of its ſpecific Gravity above that of a Fluid in which it is immers'd.

I. A Body that is ſpecifically heavier than a Fluid, when it is weigh'd therein, loſes ſo much of its Weight as is equal to the Weight of a Quantity of that Fluid as big as the Body.

Cor. 1. A Body weighs leſs in Air than in Vacuo, by the Weight of a Quantity of Air as big as the Body.

Cor. 2. A Bladder fill'd with Air, and weigh'd in Air, will weigh no more than when empty; becauſe, when the Air is taken out, the Sides of the Bladder muſt be preſs'd together; and it will not be ſo much buoy'd up by the Circumambient Air.

Cor. 3. If a Body be weigh'd in Water, and out of it, the Difference of Weight, will be the Weight of a Quantity of Water, as big as that Body: And if the abſolute Weight of the Body be divided by the ſaid Difference, the Quotient will ſhew how much that Body is heavier than Water.

Cor. 4. Hence we have an eaſy Method of finding the ſpecific Gravities of Bodies, and the Proportion of any two Metals in any Mixture. As this may be of great Uſe in diſcovering the Purity of Metals, to avoid Multiplicity of Experiments, I ſhall here ſet down a Table ſhewing the ſpecific Gravities of ſeveral Bodies, and how much they are heavier than Water.

Fine Gold - -	19,640	Clear Glaſs - -	3,150
Standard Gold	18,888	Green Glaſs -	2,620
Mercury - -	14,000	Dry Ivory - -	1,825
Lead - - -	11,325	Ebony - - -	1,177
Fine Silver -	11,091	Human Blood -	1,054
Standard Silver	10,535	Milk - - -	1,030
Copper - - - -	9,000	Sea Water -	1,030
Caſt Braſs - -	8,500	Common Water	1,000
Steel - - -	7,852	Dry Oak - -	0,925
Iron - - -	7,643	Spirit of Wine	0,866
A Diamond -	3,400	Cork - - -	0,240

Take away the Comma from theſe Numbers, or, which is the ſame, multiply them by 1000, and they will ſhew how many Ounces Avoirdupois are contain'd in a Cubic Foot of each Body.

The Uſe of this Table will beſt appear by an Example; Suppoſe, therefore, I have a Body, which I know to be a Compoſition of two Metals, and it is required to find the Quantity of each Metal without melting it.

1. By *Cor.* 3. find the ſpecificGravity of theMixture, or how many Times it is heavier than Water: Then ſubſtract the ſpecific Gravity of the lighter Metal (found in the Table) from that of the Mixture, and that of the Mixture from the heavier; the firſt Remainder ſhews the Bulk of the heavier; and the latter, the Bulk of the lighter. And if they be multiplied by their reſpective ſpecific Gravities, the Product will

ſhew the Proportion of the Weights of each Metal in the Mixture. Example;

Suppoſe the Compoſition was Fine Gold and Copper; and its ſpecific Gravity 13; that of Copper by the Table is 9, and that of Gold 19,64; therefore, 9 from 13 remains 4, the Bulk of Gold; and 13 from 19,64 remains 6,64 the Bulk of Copper; then 4 multiplied by 19,64 is 78,56 the Weight of Gold; and 6,64 multiplied by 9, is 59,76 the Weight of Copper: So that for every 78,56 Ounces or Pounds of Gold, there will be 59,76 Ounces or Pounds of Copper in ſuch a Mixture.

II. A Body ſpecifically lighter than a Fluid will ſwim upon its Surface, in ſuch a Manner, that a Quantity of that Fluid equal in Bulk with the immers'd Part of the Body, will be as heavy as the whole Body.

Cor. 1. Hence the lighter a Fluid is, the deeper a Body will ſink in it, upon which depends the Conſtruction and Uſe of the Hydrometer or Water-Poiſe.

Cor. 2. Hence a Body of the ſame ſpecific Gravity with a Fluid will neither ſink nor ſwim, but remain ſuſpended in any Part of the Fluid where it is put.

Cor. 3. From this we can eaſily find the Weight of a Ship, or any other Body that ſwims in Water; For, if we multiply the Number of Cubic Feet, which are under the Surface, by 63 the Number of Pounds in one Foot of Water, the Product will be the Weight of the whole Ship and all that is in it.

Cor. 4. In Air moſt Bodies ſink, becauſe it is very light; but in Mercury very few Bodies ſink, becauſe there are few Bodies heavier than itſelf.

Cor. 5. Two Fluids of different ſpecific Gravities being put together, the lighter will aſcend in the heavier, and ſwim upon its Surface; thus Oil aſcends in Water, and Water aſcends in Mercury.

CHAP. VI.

Of the RESISTANCE *of* FLUIDS.

THE Reſiſtance that a Body meets with, moving thro' a Fluid, is owing either to ſome remaining Coheſion of the Parts of the Fluid (there being no ſuch Thing as a perfect Fluid) or elſe to the *Inactivity* of Matter; call'd by the great Sir *Iſaac Newton* the *Inertia Materiæ*; that is, its Diſpoſition to continue in its preſent State, either of Motion or Reſt, till forc'd out of it by ſome external Cauſe; which external Cauſe, loſes as much Force as it imparts or communicates. Thus it is with Reſpect to all Bodies whatever.

Now the Reſiſtance ariſing from the Coheſion of Parts or Imperfection of the Fluidity, muſt with Reſpect to the ſame Body, be always the ſame in the ſame Space. For, let the Velocity be what it will, it is only the ſame Degree or Meaſure of Coheſion that is to be overcome in the ſame Space. So that this Reſiſtance is as the Space, and conſequently as the Velocity.

The Reſiſtance proceeding from the *Inertia Materiæ*, if the moving Body and its Velocity be the ſame, muſt be proportionable to the Quantity of Matter to be remov'd in the ſame Time or Space; that is, the Reſiſtance muſt be directly as the Denſity of the Fluid thro' which the Body is paſſing. When the ſame Body paſſes thro' the ſame Fluid, with different Degrees of Velocity, the Reſiſtance increaſes both in Proportion to the Quantity of Matter, or to the Number of Particles to be remov'd in the ſame Time, and alſo in Proportion to the Celerity with which each Particle is removed.

But the greater the Velocity of the moving Body, the greater Number of Particles muſt it ſtrike upon, and remove in the ſame Time, and the greater the Velocity, with the greater Force muſt it alſo ſtrike upon each Particle, and ſo remove it with the greater Celerity. And conſequently the Reſiſtance which is in the compound Ratio of both theſe, muſt be as the Square of the Velocity.

But now becauſe the Reſiſtance from the Coheſion of Parts, except in glutinous Fluids, is not very ſenſible; and becauſe it increaſes only in the Ratio of the Velocity, whereas the Reſiſtance from the *Inertia Materiæ*, increaſes in the duplicate Ratio of the Velocity; 'tis plain, that in ſwifter Motions this latter Reſiſtance only deſerves to be conſider'd.

The Retardation of Bodies moving in Fluids, is not always equal or proportionable to the Reſiſtance: For in a denſer Body, *cæteris paribus*, the ſame Reſiſtance occaſions a leſs Retardation: So that if two Bodies of equal Bulk and like Shape or Figure, but different Denſities, move in the ſame Fluid, the Reſiſtance which is manifeſtly proportionable to the Magnitude, or to the Extent of the Surface, muſt be equal in both: But the Momentum or Quantity of Motion in the denſer Body, being greater than that in the other, the Retardation of it muſt be the leſs. For the Reſiſtance is oppos'd to the Momentum, which is the Quantity of Matter into the Degree of Velocity. But the Retardation is oppos'd directly, and only to the Velocity. And as an equal Quantity of Motion is always deſtroy'd by an equal Reſiſtance, ſo it is plain, that an equal Quantity of Motion may be loſt, and yet not an equal Degree of Celerity. Suppoſe two Bodies to move in the ſame Fluid equal in Magnitude, and each one having 8 Degrees of Celerity, but the Momentum of the one, by Reaſon of its fourfold Denſity, to be four Times as great as the other.

In this Caſe, the Momentum or Quantity of Motion in the denſer Body is equal to 32, in the other equal to 8. Put the Reſiſtance they equally meet with in paſſing thro' the Fluid equal to 4. Then ſo much Motion muſt be deſtroy'd in each Body, and there will remain in the denſer Body, 28 Degrees of Motion, and in the other but 4. And becauſe the Momentum divided by the Quantity of Matter, gives the Celerity, and the Quantity of Matter in the denſer Body was put equal to 4, and in the other, equal to Unity, 'tis plain, that 7 will be the Degrees of Celerity remaining in the denſer Body, and 4 the Degrees of Celerity remaining in the other. So that tho' both have loſt an equal Quantity of Motion, yet the denſer Body has only loſt one Degree of Celerity, the other has loſt 4. The Celerity, therefore, loſt in paſſing thro' the Fluid, is reciprocally as the Denſity of the Body that moves. In a Word, the loſs of Motion ſuſtain'd in any Body muſt be to the Celerity, as the Momentum before this Loſs was to the Celerity of the ſame Body. So that if the Momentum of one Body, by Reaſon of its four-fold Denſity, be four Times as much as the Momentum of another Body equal as to the Celerity and Magnitude, 'tis plain, that if both loſe an equal Quantity of Motion, the Celerity loſt in the one, muſt be but one Fourth of the Celerity loſt in the other.

The Loſs of Motion is always equal to the Reſiſtance, and ſo the Retardation, where the Celerity is the ſame, reciprocally as the Momenta; that is, reciprocally as the Denſity or Quantity of Matter contain'd in the Body. In the ſame Body, indeed the Retardation is proportionable to the Reſiſtance.

The Celerity loſt in any Body muſt be proportionable or equal to that Celerity which a Force equal to the Reſiſtance would produce in the ſame Body.

The Celerity and Denſity remaining the ſame, the Momentum or Quantity of Motion muſt increaſe in the ſame Proportion with the Body itſelf; that is, in a Sphere for Example in the triplicate Ratio of the Diameter; but the Reſiſtance increaſes only as the Surface increaſes; that is, in the duplicate Ratio of the Diameter. So that the Reſiſtance increaſes in a leſs Proportion than the Momentum or Force. Therefore greater Bodies if the Celerity and Denſity be equal, muſt move longer and farther in a Fluid than thoſe that are ſmaller, becauſe their Reſiſtance and Retardation are leſs in Proportion to their Motion or Force. For this Reaſon, a great Bullet, if a proportionable Force be impreſt upon it, flies farther than one that is leſs.

The Retardations which are directly as the Reſiſtance, and reciprocally as the Momentum; *i. e.* in the direct duplicate and reciprocal triplicate, muſt be in the reciprocal Ratio of the Diameters. To ſum up all, the Retardations are directly as the Squares of the Velocity and the Denſity of the Fluids, and reciprocally as the Diameters and Denſities of the Bodies themſelves. So that the Numbers that are in the Ratio compounded of all theſe, expreſs the Retardations in all Caſes whatever.

When a Body deſcends in any Fluid (for Inſtance in Air) by Virtue of its Gravity, it is accelerated by the repeated Impulſes of Gravity, or the conſtant acting thereof upon the Body. This Acceleration would be uniform in *Vacuo*, but cannot be ſo in a Fluid, by Reaſon of the Reſiſtance of a Fluid, which increaſes as the Squares of the Velocity; and 'tis plain, that when the Body arrives to a certain Degree of Velocity, the Reſiſtance which is always increaſing in the foreſaid Proportion, will be equal to the accelerating Force of its Gravity, ſo as to balance each other; and then that Velocity ſhall be no farther increas'd. What has been ſaid of the Deſcent of ſpecifically heavier Bodies, may eaſily be apply'd to the Aſcent of ſuch Bodies as are ſpecifically lighter than the Fluid in which they are placed.

CHAP.

CHAP. VI.

PNEUMATICS;

OR,

The PROPERTIES *of* AIR.

I. AIR is that thin tranſparent Fluid in which we live and breathe: Its firſt Property is *Weight*, or *Gravity*, which may be demonſtrated by ſeveral Experiments.

1. Take the Air out of a Glaſs Globe or other Veſſel, with the Air-Pump; then having weigh'd it, let the Air in again, and weigh it a ſecond Time, it will be found conſiderably heavier.

2. The ſame Thing is prov'd by condenſing Air in a Veſſel.

By ſeveral Experiments of this Nature, we find, that a Cubic-Foot of Air, weighs about one Ounce and one *7th*; and therefore, it is about 880 times lighter than Water; ſometimes more, at other times leſs.

II. That large Collection of Air which covers the Earth, all round to a conſiderable height, is call'd the Atmoſphere; and as Air is heavy, this Atmoſphere muſt preſs with a great Force on the Surface of the Earth, and all other Bodies: The Quantity of which Preſſure is found by this Experiment. Take two hollow Hemiſpheres, 4 Inches Diameter, and put their Brims together; then pump the Air out of them, and they will require about 190 Pounds to pull them aſunder;

ſunder: And therefore, the Atmoſphere preſſes with the Force of about 15 Pounds upon every Square Inch, ſometimes more, at other Times leſs; and upon all Bodies that are bigger or leſs, the Preſſure is proportionably more or leſs; ſo that upon the Body of a middle ſiz'd Man, there will be continually the Preſſure of 20 or 30 thouſand Pounds.

III. The Preſſure of the Atmoſphere may be more exactly determin'd by this Experiment.

Take a Glaſs Tube about 3 Feet long, and fill it with Mercury; then put your Finger upon the open End, and invert it in a Veſſel of the ſame Fluid, without letting in any Air; and the Mercury in the Tube will remain ſuſpended 29 Inches and an half above the Surface thereof in the Veſſel; ſometimes more, at other Times leſs. This Mercury is kept up in the Tube by the Preſſure of the Atmoſphere; for, if it be put under a Receiver, and the Air taken out, the Mercury falls down, and when the Air is let in again, it riſes to the ſame Height as before: Therefore, the Atmoſphere's Preſſure on the Surface of the Earth, is equal to the Weight of 29 Inches and an half of Mercury, which agrees exactly with the other Experiment; for a Column of Mercury, 4 Inches Diameter, and 29 Inches and a half long, will be found to weigh 190 Pounds, the ſame that was requir'd to ſeparate the Hemiſpheres of 4 Inches Diameter, when the Air was exhauſted.

If the laſt Experiment was to be tried with a long Tube and Water, it would remain ſuſpended 33 Feet above the Surface in the Veſſel; and therefore, the Preſſure of the Atmoſphere is equal to the Weight of 33 Feet of Water; that is, if the Surface of the Earth, or any Part of it was cover'd 33 Foot deep with Water, that Water would preſs as much upon the Surface of the Earth as it is preſs'd by the Atmoſphere.

IV. The ſecond Property of Air is Elaſticity; that is, a certain ſpringing Force, by which it always endeavours to expand, ſwell, or encreaſe itſelf in Bulk.

Many Experiments may be brought to prove this wonderful Property of Air.

1. Tie up a little Air in a Bladder, and put it under a Receiver, and when the Air is pump'd out, that in the Bladder will ſwell up the Side ſo as to fill it.

2. Take a Glaſs Bottle, and put it with the Mouth downward in a Veſſel of Water, under a Receiver, and exhauſt the Air, and the Air in the Bottle will be obſerv'd to ſwell and bubble up thro' the Water.

The elaſtick or ſpringing Force of Air, is equal to the Preſſure of the Atmoſphere, becauſe it always ſuſtains that Preſſure. Thus the Air in a Bottle, or any other Veſſel, will expand itſelf with a Force equal to that with which it is preſs'd, becauſe Action and Re-action are equal: And hence the Elaſticity of a ſmall Quantity of Air, is equal to that of a great Quantity.

V. The Denſity of the Air is always as the Force that preſſes; and therefore, the Air towards the upper Part of the Atmoſphere, being leſs preſs'd, will expand itſelf, and thereby become thinner than that at the Surface of the Earth.

It is demonſtrated by Mathematicians, That if Altitudes in the Air be taken in Arithmetical Proportion, the Rarity of the Air will be in a Geometrical Proportion: For Inſtance,

At the Altitude of	Miles from the Surface of the Earth, Air is	Times thinner than at the Surface.
7	4	
14	16	
21	64	
28	256	
35	1024	
70	1048576	

Hence it will be eaſy to calculate, that a Cubic-Inch of common Air, at the Altitude of 500 Miles would be ſo much rarified, that it would fill a Sphere as large as the Orbit of Saturn: And therefore, the Planets may move thro' the upper Regions of the Heavens, for many thouſand Years without ſuffering any ſenſible Reſiſtance.

According to this Rule for finding the Rarity of the Air at any Height, there will remain ſome Air to an infinite Diſtance; and yet the Rarity at the Height of about 40 or 50 Miles is ſo great, that what is above, is inconſiderable: And therefore, the Height of the Atmoſphere is generally reckon'd about 45 Miles.

VI. The third and moſt remarkable Property of Air, is, That it is rarified or made to ſwell with Heat, which may be prov'd by many Experiments.

Wind is a neceſſary Conſequence of this Property of Air; for when it is heated by the Sun, or otherways, it will ſwell and drive the adjacent Air away; and ſo by various Degrees of Heat in different Places there will ariſe various Winds.

Cor. 1. When Air is very much heated, it will aſcend towards the upper Part of the Atmoſphere, and the adjacent Air will ruſh in to ſupply its Place; and therefore, there will be a Stream or Current of Air from all Parts towards the Place where the Heat is.

Cor. 2. Hence we ſee the Reaſon why the Air ruſhes with ſuch Force into a Glaſs-houſe, or towards any Place wherein a great Fire is made.

Cor. 3. From this we ſee the Reaſon why Smoke is carried up a Chimney, and why the Air ruſhes in at the Key-hole of the Door, or any ſmall Chink, when there is a Fire in the Room.

Cor. 4. Take it in general, the Air will preſs towards that Part of the World where it is moſt heated.

Cor. 5. Hence we can eaſily account for the Trade-Winds, which about the Equator blow conſtantly from Eaſt to Weſt; for, when the Sun ſhines perpendicularly on any Part of the Earth, it will heat the Air in that Part very much; which will therefore riſe upward, and the adjacent Air will ruſh in to fill up the Vacuity, and conſequently cauſe a Stream or Current of Air from all Parts towards the Sun; but as the Sun, with reſpect to the Earth, moves from Eaſt to Weſt, the common Courſe of the Air will be that Way too, continually preſſing after the Sun; and therefore, at the Equator, where the Sun ſhines ſtrongly, there will be a continual Eaſterly-wind; but on the North-Side, it will incline a little to the North; and on the South-Side, to the South.

This general Courſe of the Wind about the Equator is chang'd in ſeveral Places, and upon ſeveral Accounts. As,

1. "The Attraction of the Moon on the Meri-
" dian, may be reaſonably ſuppos'd to raiſe a Swell of
" the Air, no leſs than of the Water in the Tides.
" 2. Certain Exhalations that riſe out of the Earth,
" at certain Times, and from certain Places, in
" Earthquakes eſpecially, and from Volcanos. 3.
" The Fall of great Quantities of Rain, Hail, or
" Snow, cauſing thereby a ſudden Condenſation of

" Contraction of the Air. 4. The ſudden melting of " Snows, &c. on the higher Mountains cauſing the " Condenſation near them ſuddenly to ceaſe. 5. " Burning Sands that often retain the ſolar Heat to a " Degree incredible to thoſe who have not felt it, " cauſing a more than ordinary Degree of Rarefaction " in the Air contiguous to them. 6. The Oppo- " ſition of high Mountains that reflect the Winds, " and alter the Line of their Direction. 7. The " Declination of the Sun towards the North or South, " heating the Air either in this or that Part of the " World; all which particular Cauſes may chance " either to conſpire with, and ſtrengthen the general " one before cited, or may oppoſe in Part and leſſen " its Efforts, according to the Diverſity of Time, " Place, and Circumſtance that in the Courſe of " Things may happen."

To theſe Particulars, or ſuch like, is owing, 1. The manifeſt Irregularity and Uncertainty of the Winds in Climates far diſtant from the Equator, as in moſt Parts of Europe. 2. Thoſe periodical Winds, which in the Indian Sea blow half a Year one Way; and the other half another. 3. Thoſe Winds which on the Coaſts of *Guniea*, and on the weſtern Coaſts of *America* blow always from Weſt to Eaſt. 4. The Sea Breezes, which in hot Countries, blow generally from the Sea to the Land, in the Day Time; and the Land Breeze, which blows in the Night; and in ſhort, all thoſe Storms, Hurricanes, Whirlwinds, and all the Irregularities which happen at different Times and Places, muſt proceed from ſome ſuch Cauſes as thoſe before mentioned.

Particular Deſcriptions of the Motions of Air in various Parts of the World might be eaſily given; but as this would be too tedious for the preſent, I ſhall therefore

fore proceed to the Explanation of thoſe Properties of Air, which more immediatly concern us.

VI All common Air is impregnated with a certain vivifying Spirit, or *Pabulum Vitæ*, which is neceſſary to continue the Lives of Animals; and this vivifying Spirit in a Gallon of Air, is ſufficient to feed one Man, for the Space of a Minute, and not much longer.

The vivifying Spirit of Air is deſtroy'd by paſſing thro' the Lungs of Animals, as may be prov'd by many Experiments: And hence it is, that an Animal dies when put under a Receiver, tho' no Air be taken from it.

This vivifying Spirit ſeems to be infus'd in Water; for Fiſh die when they are excluded from freſh Air, as in a Pond that is cloſely frozen over.

The little Eggs of Inſects, ſtop'd up in a Glaſs, do not produce their young, tho' aſſiſted by a kindly Heat; the Seeds alſo of Plants mix'd with good Earth, and inclos'd in a Glaſs, will not grow or give any Signs of Life; ſo that freſh Air is abſolutely neceſſary both for the Production, and Continuation of the Lives of Animals and Plants.

This vivifying Quality in Air, is alſo deſtroy'd by the Air's paſſing thro' Fire; particularly Charcoal-Fire, or the Flame of Sulphur; as may be demonſtrated by ſeveral Fxperiments with the Air-Pump.

Hence ſmoking Chimnies muſt be very unwholeſome, eſpecially if the Rooms they are in be ſmall and very cloſe.

Air is alſo vitiated by remaining cloſely pent up in any Place for a conſiderable Time; or perhaps by being mixt with malignant Steams and Particles flowing from the neighbouring Bodies; or laſtly, by the Corruption and Putrefaction of the vivifying Spirit, as in the Holds of Ships, in Oil Ciſterns, or Wine Cellars, that have been ſhut up for a conſiderable Time. The Air in any of them will ſometimes be ſo much vitiated, as to be immediate Death to any Thing that comes into it.

"Air that has loſt its vivifying Spirit, is call'd *damp*, "not only becauſe it is fill'd with humid or moiſt Va- "pours, but, becauſe it deadens Fire, extinguiſhes "Flames, and deſtroys Life."

The dreadful Effects of Damps are ſufficiently known to ſuch as are converſant in Mines.

"If Part of the vivifying Spirit of Air in any Coun- "try begins to putrefy, the Inhabitants of that Coun- "try will be Subject to an epidemical Diſeaſe, which "will continue till the Putrefaction be over. And "as the putrefying Spirit occaſions the Diſeaſe, ſo "if the diſeas'd Body contributes towards putrefying "the Air, then the Diſeaſe will not only be epide- "mical, but peſtilential and contagious."

The Atmoſphere is the common receptacle of all the Effluvia or Vapours ariſing from different Bodies, whether grateful or fœtid; of the Steams and Smoke of Things burnt or melted; the Fogs or Vapours proceeding from damp watery Places, and of the Effluvia from ſulphurous, nitrous, aſcid and alcaline Bodies: In ſhort, whatever may be call'd Volatile, riſes in the Air to a greater or leſs Height, according to its ſpecific Gravity.

When the Effluvia which ariſe from aſcid and alkaline Bodies, meet each other in the Air, there will be a ſtrong Conflict, or Fermentation, which will ſometimes be ſo great, as to produce a Fire; then, if the Effluvia be combuſtible, the Fire will run from one Part to another, juſt as the inflammable Matter happens to lie.

Any one may be convinc'd of this, by mixing an aſcid and alkaline Fluid together, as the Spirit of Nitre, and Oil of Cloves; for, when they are mix'd, a ſudden Ferment, with a fine Flame will ariſe, and ſometimes (if the Ingredients be very pure and ſtrong) there will be a ſudden Exploſion.

Thus any one of the Tribe of Aſcids being mix'd with one of the Alkalies, will produce ſome Degree of Fermentation: And even the Effluvia of ſome of them meeting in the Air, with thoſe of the other, will begin a Degree of Efferveſcence, ſo as to become ſometimes viſible.

Whoever conſiders the Effects of Fermentation, cannot long be at a loſs for the Cauſe of the dreadful Phænomena of Thunder and Lightning; for the Effluvia of ſulphurous and nitrous Bodies, and others that may riſe into the Atmoſphere, will ferment with each other, and take Fire very often of themſelves; ſometimes by the Aſſiſtance of the Sun's Heat.

If the inflammable Matter be thin and light, it will riſe to the upper Part of the Atmoſphere, where it will flaſh without doing any Harm; but, if it be denſe, it will lie nearer the Surface of the Earth, where taking Fire, it will explode with a ſurprizing Force, and by its Heat rarify, and drive away the Air, kill Men and Cattle, ſplit Trees, Walls, Rocks, *&c.* and be accompanied with terrible Claps of Thunder.

The Heat of Lightning appears to be quite different from that of other Fires; for, it has been known to run thro' Wood, Leather, Cloth, *&c.* without hurting them, while it has broken and melted Iron, Steel, Silver, Gold and other hard Bodies. Thus it has melted or burnt aſunder a Sword, without hurting the Scabbard; and Money in a Man's Pocket, without hurting his Clothes: The Reaſon of this ſeems to be, that the Particles of the Fire are ſo fine, as to paſs thro' ſoft looſe Bodies without diſſolving them while they ſpend their whole Force upon the hard ones; in the ſame Manner, *Aqua Regia* diſſolves Gold, but does not hurt Silver, or other ſofter Metals.

Here I cannot omit taking notice, that I have ſeen Knives and Forks, that had been ſtruck with Lightning, and ſome of them melted or burnt, which had a very ſtrong magnetical Virtue 6 or 7 Years after they were ſtruck. And, I have been told, that Lightning ſtriking upon the Mariner's Compaſs, will ſometimes turn it round, and often make it ſtand the contrary Way, or with the North Point toward the South.

X. Much of the ſame Kind with Lightning, are thoſe Exploſions which ſometimes happen in Mines, call'd the Fulminating or Fire Damps; theſe are occaſion'd by ſulphurous and nitrous, or rather oleaginous or inflammable Particles, riſing probably from the Mine and mixing with the Air, where they will take Fire, by the Lights which the Work-men are oblig'd to make uſe of. The Fire being kindled, will run from one Part of the Mine to another, like a Train of Gun-pouder, juſt as the Combuſtible Matter happens to lie; and as the Elaſticity of Air is encreas'd with Heat, that in the Mine will conſequently ſwell very much; and ſo for want of Room, will explode with a greater or leſs Force, according to the Denſity of the combuſtible Vapours. It has been known ſo ſtrong, as to blow up the Mine; and at other Times ſo weak, that when it had taken Fire at the Flame of a Candle, it has been eaſily blown out.

Air that will kindle at the Flame of a Candle, may be produc'd thus.

Having emptied a Receiver, let the Air run into it thro' the Flame of the Oil of Turpintine, then remove the Cover of the Receiver, and holding a Candle to that Air, it will take Fire and burn quicker or ſlower according to the Denſity of the oleaginous Vapour.

If ſuch combuſtle Matter as this before mention'd, ſhould kindle in the Bowels of the Earth, where there is little or no Vent, it will produce Earthquakes, and violent Storms or Hurricanes of Wind, when it breaks forth into the Air.

An artificial Earthquake may be made thus. Take 10 or 15 Pounds of Sulphur, and as much of the Filings of Iron, and make them into the Conſiſtence of Paſte with common Water; this being buried under the Ground, in 8 or 10 Hour's Time, will vomit out Flames, and cauſe the Earth to tremble all round about the Place, to a conſiderable Diſtance.

From this Experiment we have a very natural Account of the Fire of Mount *Ætna*, *Veſuvius* and other Vulcanos; they being probably Mountains ſet on Fire at firſt, by the Mixture of ſuch metaline and ſulphurous Particles; and from the like Cauſe, proceeds the Heat of Bath-waters, and other hot Springs.

CHAP. VII.

Of HEAT, *and the* RAREFACTION *of* BODIES.

I. IF a Body be immers'd in a Fluid, it will always become of the ſame Degree of Heat with that Fluid: And therefore, all ſimple Bodies are of the ſame Heat with the ambient Air, if they be not alter'd by ſome Accident; as by Friction, Putrefaction, Fermentation, vital Motion, or the Approach of ſome Body already hot.

Some Bodies will heat or cool much ſooner than others; as Mercury, for Inſtance, will gain or loſe a Degree of Heat, in about half the Time, that the ſame Bulk of Water under the ſame Circumſtances will; and Spirit of Wine heats or cools faſter than Water, in the Ratio of 3 to 4; but Air heats or cools 20 or 30 times faſter than Mercury.

Hence Air would be the beſt Fluid for making Thermometers, if it was not compreſſible; but as it is, Mercury will be propereſt, not only becauſe it is very ſuſceptible of Heat, but becauſe it is more denſe and leſs glutinous.

II. It has been before ſhewn, that Metals expand with Heat; the ſame may be eaſily demonſtrated of Fluids; in ſeveral of which, the Proportion of Expanſions is as follows; Air 100. Spirit of Wine 16,7. Linſeed-Oil 10. Water 2,78. Mercury 2,7.

From the Heat of Water juſt freezing, to the Heat of a Human Body, Air will ſwell about one 4th Part of its Bulk. Spirit of Wine, by the like Increaſe of Heat, will ſwell one 24*th* Part of its Bulk. Linſeed Oil, one 40*th*. And Water or Mercury one 144*th* Part.

Hence I find, that 32 Gallons of Spirit of Wine in Winter, will make 33 in Summer; or, if it be expos'd to the meridian Sun in Summer, it will make almoſt 34; and in other Bodies, the Increaſe will be as above.

III. The Expanſion of all Fluids is proportionable to the Degree of Heat; that is, with a double or treble Heat, a Fluid will expand two or three Times as much.

Upon theſe Principles, depends the Conſtruction of the Thermometer, which is generally a Glaſs-Globe and Tube; as A B. The Globe and Part of the Tube are fill'd full with a Fluid, commonly Spirit of Wine ting'd, that it may be more eaſily ſeen in the Tube. Fig. 12.

This done, when the Spirit ſwells by Heat within the Globe, it will riſe up the Tube to a Height proportionable to the Degree of Heat or Expanſion, and will be very uſeful for finding the Heat of the Air, or of other Bodies, at different Times and Places, the Heat of different Rooms, or of hot Beds, *&c.*

From the Conſtruction of the Thermometer it is eaſy to ſee, that the larger the Globe is, and the ſmaller the Tube, the more nicely it will ſhew the Degrees of Heat: If the Globe be one Inch diameter, and the Tube about one 6*th* of an Inch, and fill'd with pure Spirit of Wine, it will riſe and fall about 20 Inches by the Difference of Heat in Summer and Winter.

IV. It is to be wiſh'd, that all thoſe who make Thermometers would obſerve to graduate them according to ſome fix'd and determin'd Scale, that ſo they might be univerſally intelligible; the want of which, has often render'd Obſervations made by them of little or no Uſe; for the Obſervations made upon the Heat of Bodies, in different Parts of the World, with different Thermometers, could not be compar'd with each other.

The great Sir *Iſaac Newton*, obſerving that Heat had a great Part in the Operations of Nature, thought, that ſettling the Scale of Thermometers was a Thing well worth his Notice: And, as he ſeldom took any Thing in Hand, but what he carried to a greater Length, than any had done before him; ſo in this, he ſhews a Method of conſtructing and graduating Thermometers, that ſhall be univerſally intelligible, and agree with each other in all Parts of the World; and by his Example, ſeveral others have ſince made Scales of their own; and tho' there be none which I think ſo good as Sir *Iſaac*'s, yet, becauſe *Fahrenheit*'s Scale, is at preſent more in Vogue, I ſhall ſhew the Conſtuction and Graduation of Thermometers according to that Scale.

Firſt, Let the Globe or Bulb of the Glaſs, and Part of the Tube be fill'd with a Fluid; then immerſe the Bulb in Water juſt freezing, or Snow juſt thawing, and where the Spirit ſtands in the Tube, there place Number 32, to denote the freezing Point; then hold the Bulb of the Glaſs in your Hand, or rather put it under your Arm-pit, when your Body is of a moderate Heat, ſo that it may acquire the ſame Degree of Heat with your Skin; and when the Spirit has riſen as high as it will, there place Number 97; then divide the Diſtance between theſe Numbers into 65 equal Parts; and continue thoſe Diviſions both above 97, and below 32, and number them accordingly.

V. This may be done in any Part of the World; for it is found, that the freezing Point is always the ſame in all Places, and the Heat of the Human Body varies but very little; ſo that the Thermometers made in this Manner, will perfectly agree with one another; and the Heat of ſeveral Bodies will be ſhewn by it, and expreſs'd by the Number upon the Scale, thus;

Air, in ſevere cold Weather, in our Climate, from 15 to 25. Air in Winter, from 26 to 42. Air in Spring and Autumn, from 43 to 53. Air in Summer, from 54 to 64. Air at Mid-Summer, from 65 to 68. Extreme Heat of the Summer Sun, from 86 to 100. Butter juſt melting, 95. Heat of Human Blood, 98 or 99. A Hen hatching Eggs. 106 or 108. Wax juſt melting, 109. Alkohol boils with gr. 174 or 175. Brandy with gr. 190. Water 212 *. Oil of Turpintine 550. Lead melts with gr. 540. And Tin with 408. Milk freezes at about gr. 30. Urine 28. Vineger 28. Blood 27 or 26.

VI. When Water is heated beyond a certain Degree, the Particles thereof are made to repel one another, and conſtitute an elaſtick Fluid, which is generally call'd Steam or Vapour.

Steam has theſe Properties common to Air, *viz.* it is heavy, elaſtic, compreſſible, and hath its Elaſticity increas'd with Heat: But Cold quickly deſtroys

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* The Heat required to make a Fluid boil, is greater or leſs, according to the Preſſure of the Atmoſphere; for the Heat of boiling Water is about 2 Degrees more, when the Mercury in the Barometer ſtands at 30, than when it ſtands at 29: Hence we ſee, why warm Water boils ſo violently, when the Preſſure of the Atmoſphere is taken off, as in an exhauſted Receiver: And therefore, if we had no Atmoſphere preſſing on the Surface of the Earth, all Rivers, Ponds, and even the Sea, would boil with the Sun's Heat; and yet it would be impoſſible to make Water warm.

its Elaſticity, and turns it into Water again; as is eaſily demonſtrated by the Æolipile.

Upon theſe Properties of Steam, depends the Conſtruction of one of the moſt curious and uſeful Machines amongſt Mankind; I mean the Fire-Engine, generally made uſe of to pump Water out of Mines.

The Force of heated and confin'd Steam, is very well known by its Effects, in raiſing Water, burſting Glaſs-Spheres, and digeſting Bones, *&c.* particularly of the Steam of Nitre, as in firing Gun-powder.

Steam or Vapour, heat'd red-hot, is call'd Flame; as the Vapour, or Fume, ariſing from a Candle juſt blown out; for, another Candle being held to it, will ſet it on Fire.

Steam or Vapour aſcends, ſo long as its Elaſticity keeps the Particles ſo far from each other, as to make the Vapour lighter than Air; but, when its Elaſticity is decreas'd by Cold, it is condens'd, and ſo falls again to the Earth, in Miſt or Rain.

CHAP. VIII.

Of Hydroſtatic, and Pneumatic ENGINES.

THE Common Pump, with which we draw Water out of Wells, is one of theſe Engines; it conſiſts of a Tube or Pipe open at both Ends, and a Piſton, Bucket, or Sucker which fits the Tube pretty tight; ſo that when it is drawn up, it drives the Air and Water before it, and takes off the Preſſure of the Atmoſphere; then the Atmoſphere preſſing on the Well-Water, drives it up the Tube thro' a Valve *, to fill that Part of the Tube that is left by the Piſton; then the Piſton being thruſt down again, will endeavour to drive the Water back the ſame Way it came; but the Valve claps over the Paſſage, and ſtops it, ſo that the Water is obliged to paſs thro' the Piſton, which, for that Purpoſe, is perforated, and has another Valve plac'd upon it in the ſame Manner, as that before deſcrib'd; and when the Piſton is drawn up again, the Valve plac'd therein cloſes; and therefore, all the Water that is above, will be lifted up as before;

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* A Valve is generally a Piece of Leather, fixt like a Trap Door, in ſuch a Manner, that it will eaſily open, and let any Fluid paſs one Way; but when it endeavours to retutn, the Valve claps cloſe, and ſtops the Paſſage: Of theſe, there muſt be, at leaſt, two belonging to every Pump.

A Valve of an Air-Pump is only a little Slip of wet Bladder tied over a little Hole, ſo that Air can eaſily paſs thro' that Hole one Way, and not another.

and ſo the Piſton being pull'd up, and thruſt down alternately, the Water is thereby drawn out of the Well.

Cor. 1. As it is the Preſſure of the Atmoſphere which cauſes the Water to riſe, and follow the Piſton, as it is drawn up; therefore, the perpendicular Height from the End of the Piſton to the Surface of the Water in the Well, muſt always be leſs than 33 Feet; (by § 3 Chap. 6.) and yet Water may be rais'd by a Pump to any Height, if we make the Rod of the Piſton long enough.

Cor. 2. The Force requir'd to work a Pump (by § 4. and 7. Chap. 4.) will be as the Height to which the Water is rais'd, and as the Square of the Diameter of the Pump, in that Part where the Piſton works.

The Wideneſs or Narrowneſs of the Pump in any other Part, beſides that in which the Piſton works, (by § 6. Chap. 4.) does not make the Pump either more or leſs difficult to work, except what Difference may ariſe from Friction; upon which Account, the wider the better,

From theſe Principles, it will be eaſy to find the Dimenſions of a Pump that ſhall work with a given Force, and draw Water from any Depth; but, as theſe Calculations have (either for want of Skill or Induſtry) been generally neglected by Pump-Makers, I have for their Eaſe, calculated the following Table, in which, I ſuppoſe the Handle of the Pump to be a Lever, increaſing the Power 5 times; and that one Man, as I have often found, can work a Pump 4 Inches Diameter, and 30 Feet long; and diſcharge about 27 Gallons and an half of Water, Engliſh Wine Meaſure, in a Minute: But, if it be required to find the Diameter of a Pump, that ſhall with the ſame

Eaſe, draw Water from any other Depth look for that Depth in the 1*ſt* Column; and over againſt it in the 2*d*. you have the Diameter, or Width of the Pump requir'd. And in the 3*d* Column, you find the Quantity of Water which one Man can diſcharge in a Minute.

Depth of the Well.	Diameter of the Pump.		Water diſcharg'd in a Minute, Engliſh Wine Meaſure.	
Feet.	Inches.	100 Parts.	Gallons	Pints.
10	6.	93	81	6
15	5.	65	54	4
20	4.	90	40	7
25	4.	38	32	6
30	4.	00	27	2
35	3.	70	23	3
40	3.	47	20	4
45	3.	26	18	1
50	3.	10	16	3
55	2.	95	14	7
60	2.	83	13	5
65	2.	71	12	4
70	2.	62	11	5
75	2.	53	10	7
00	0.	44	10	2

II. The Air Pump is in Effect the ſame as the Water-Pump, conſiſting of a Piſton and Barrel, or ſometimes two Piſtons and two Barrels, communicating with a Receiver. When the Piſton is drawn up, being made to fit the Barrel ſo tight, that no Air can paſs by, it will leave a Vacuity in the lower End of the Barrel; then the Air in the Receiver will by its Elaſticity open the lower Valve, and ruſh thro' to fill that Vacuity; the Piſton going down again, the lower Valve ſhuts, and the upper one opens, as in the Water-Pump: Thus the Piſton goes up and down alternately, and takes out the Air; but the Quantity taken out by any one Stroke, will always be as the Denſity thereof in the Receiver: Suppoſe, for Example, the Capacity of the Receiver and Pump be equal, then every Stroke of the Pump will take out half the Air that is left in the Receiver at any Time; as might be eaſily demonſtrated from the Properties of Air before explain'd: And therefore, it is impoſſible to take all the Air out of a Receiver; becauſe, there will always be as much left, as was taken out the laſt Turn of the Pump.

III. The Condenſing Engine is nothing but a Syringe, with the Valves turn'd the contrary Way.

IV. The Diving-Bell, is a large Veſſel made of Wood or Copper, with Weights about the Bottom, in order to make it ſink when full of Air, with the Mouth downward: The Diver ſitting under this Bell, is let down with the included Air to the Depth deſir'd.

The Management of this Machine depends upon the Knowledge of the following Principles.

1. That a Body immers'd in a Homogeneal Fluid, is always preſs'd with a Force propotrionable to its Diſtance from the Surface.

2. That the Denſity of Air is always as the Force that preſſes it, *viz.* with 2, or 3 times the Preſſure, it will be preſs'd into half, or one 3*d* of the Space it poſſeſſed before.

3. That Air is vitiated by paſſing thro' the Lungs of Animals.

A further Deſcription of the diving Bell take in the Words of the ingenious Dr. *Halley*.

“ The Bell I made uſe of was of Wood, containing
“ about ſixty Cubic-Feet in its Concavity, and
“ was of the Form of a *Truncate Cone*, whoſe Diameter
“ at the Top was three Feet, and at Bottom
“ five. This I coated with Lead ſo heavy, that it
“ would ſink empty, and I diſtributed the Weight ſo
“ about its Bottom, that it would go down in a perpendicular
“ Situation, and no other. In the Top,
“ I fixed a ſtrong, but clear, Glaſs, as a Window
“ to let in the Light from above; and likewiſe a
“ Cock to let out the hot Air that had been breathed;
“ and below, about a Yard under the Bell, I placed
“ a *Stage* which hung by three Ropes, each of which
“ was charged with about one hundred Weight, to
“ keep it ſteddy. This Machine I ſuſpended from
“ the Maſt of a Ship by a *Sprit*, which was ſufficiently
“ ſecured by *Stays* to the Maſt-head, and was
“ directed by *Braces* to carry it over-board, clear of
“ the Ship-ſide, and to bring it again within-board
“ as Occaſion required.

“ To ſupply Air to this Bell when under Water,
“ I cauſed a couple of Barrels, of about thirty ſix
“ Gallons each, to be caſed with Lead, ſo as to ſink
“ empty; each having a Bung-hole in its loweſt Part
“ to let in the Water, as the Air in them condenſed
“ on their Deſcent; and to let it out again when
“ they were drawn up full from below. And to a
“ Hole in the uppermoſt Part of theſe Barrels, I fixed
“ a Leathern Trunk or *Hoſe*, well liquored with
“ Bees-Wax and Oil, and long enough to fall below
“ the Bung-hole, being kept down by a Weight appended;
“ ſo that the Air in the upper Part of the

“ Barrel could not eſcape, unleſs the lower Ends of theſe *Hoſe* were firſt lifted up.

“ The Air-Barrel being thus prepared, I fitted them with Tackle proper to make them riſe and fall alternately, after the Manner of two Buckets in a Well; which was done with ſo much Eaſe, that two Men, with leſs than half their Strength, could perform all the Labour required; and in their Deſcent, they were directed by Lines faſtned to the under Edge of the Bell; the which paſſed thro' Rings placed on both Sides of the Leathern *Hoſe* in each Barrel; ſo that ſliding down by thoſe Lines, they came readily to the Hand of a Man, who ſtood on the Stage on purpoſe to receive them, and to take up the Ends of the *Hoſe* into the *Bell*. Thro' theſe *Hoſe*, as ſoon as their Ends came above the Surface of the Water in the Barrels, all the Air that was included in the upper Parts of them, was blown with great Force into the Bell, whilſt the Water entered at the Bung-holes below and filled them; and ſo ſoon as the Air of the one Barrel had been thus received, upon a Signal given, that was drawn up, and at the ſame Time, the other deſcended; and by an alternate Succeſſion, furniſhed Air ſo quick, and in ſo great Plenty, that I myſelf, have been one of five, who have been together at the Bottom, in nine or ten Fathoms Water, for above an Hour and a half at a Time, without any Sort of ill Conſequence; and I might have continued there as long as I pleaſed, for any Thing that appeared to the contrary. Beſides, the whole Cavity of the Bell was kept entirely free from Water, ſo that I ſat on a Bench, which was diametrically placed near the Bottom, wholly dreſſed with all my Cloaths on. I only obſerved, that it is neceſſary to be let down gradually at firſt, as about twelve Foot at a Time; and then to ſtop and drive out the Water that entred, by receiving three or four Barrels of freſh Air, before I deſcended farther. But being arrived at the Depth deſigned, I then let out as much of the hot Air that had been breathed, as each Barrel would repleniſh with cool, by Means of the Cock at the Top of the Bell; thro' whoſe Aperture, tho' very ſmall, the Air would ruſh with ſo much Violence, as to make the Surface of the Sea boil, and cover it with a white Foam, notwithſtanding the great Weight of Water over us.

“ Thus I found I could do any Thing that was required to be done juſt under us; and that, by taking off the Stage, I could, for a Space as wide as the Circuit of the Bell, lay the Bottom of the Sea ſo far dry, as not to be over Shoes thereon. And by the Glaſs-Window, ſo much Light was tranſmitted, that when the Sea was clear, and eſpecially when the Sun ſhone, I could ſee perfectly well to write or read, much more to faſten and lay hold on any Thing under us, that was to be taken up. And by the Return of the Air-Barrels, I often ſent up Orders, written with an Iron-Pen, on ſmall Plates of Lead, directing how to move us from Place to Place, as Occaſion required. At other Times, when the Water was troubled and thick, it would be dark as Night below; but in ſuch a Caſe, I have been able to keep a Candle burning in the Bell as long as I pleaſed, notwithſtanding the great Expence of Air requiſite to maintain Flame.

“ This I take to be an Invention applicable to various Uſes; ſuch as *Fiſhing* for *Pearl*, *Diving* for *Coral*, *Spunges*, and the like, in far greater

" Depths than has hitherto been thought poſſible:
" Alſo for the fitting and plaining of the Foundation
" of Moles, Bridges, *&c.* upon rocky Bottoms; and
" for the cleaning and ſcrubbing of Ships Bottoms,
" when foul, in calm Weather at Sea. But, as I
" have no Experience of theſe Matters, I leave
" them to thoſe that pleaſe to try. I ſhall only in-
" timate, that by an additional Contrivance, I have
" found it not impracticable for a Diver to go out of
" our Engine to a good Diſtance from it, the Air
" being conveyed to him with a continued Stream by
" ſmall flexible Pipes; which Pipes may ſerve as a
" Clew to direct them back again, when he would
" return to the Bell."

The Contrivance here mentioned, was a Veſſel made in the Shape of a Bell, ſo big as to go over a Man's Head and Shoulders; and when they came to the Bottom of the Sea, one of the Divers took this Veſſel, and having put it over his Head, walk'd out of the Bell upon the Bottom of the Sea, round about, and had the Air convey'd to him by flexible Tubes.

V. The common Barometer, or Weather-Glaſs, is only a Column of Mercury, ſuſpended in a Glaſs-Tube, by the Preſſure of the Atmoſphere; its Conſtruction has been ſhewn before, Chap. 6. §. 3. or it may be made thus; Take a Glaſs-Tube, about 34, or 35 Inches long, ſuch as is repreſented *Fig.* 11. Seal it cloſe at b, fill it quite full with Mercury, then turn it up to the Poſition you ſee it, in the *Fig.* and the Mercury will fall down to B, and leave the upper Part of the Tube empty. The Reaſon why it does not fall to the Bottom, is, Becauſe the Atmoſphere preſſes upon the Mercury at E, and keeps it ſuſpended; and therefore, the perpendicular Height from E to B, will always be proportionable to that Preſſure.

Whenever the Preſſure of the Atmoſphere, on any Part of the Earth increaſes, the Mercury in the Barometer will riſe; the Denſity of the Air (by Chap. 7. §. 5.) in that Part will increaſe, and the Clouds floating in the Atmoſphere will be buoy'd up to a greater Height; and there will conſequently follow clear and ſerene Weather; and on the contrary, when the Preſſure of the Atmoſphere is by any Means decreas'd, the Mercury in the Barometer will fall; the Air will become thinner, and the Clouds floating in the Atmoſphere will ruſh in to that Place; and therefore there will follow cloudy or rainy Weather: And thence the Barometer came to be call'd, *The Weather-Glaſs*, becauſe of its Property of predicting the Weather.

The Weight of the Atmoſphere may be in Effect diminiſh'd, when its Preſſure is interrupted by the Courſe of violent Winds paſſing over any Place. Hence the Barometer ſinks in ſtormy Weather.

The greateſt perpendicular Height of the Mercury in the Tube, above the Surface thereof in the Baſon at the Bottom, is 31 Inches; and the leaſt Height that has been obſerv'd, is 27,9 Inches. I mean, when the Barometer is plac'd not far from the Surface of the Sea; but, if it be carried to the Top of a very high Hill, the Mercury will fall conſiderably, becauſe it will be only preſs'd by the Air that is above it. In going perpendicularly upwards about 1000 Feet, the Mercury will fall one Inch; which by the by, ſhews that a Column of Air 1000 Feet long, is equal in Weight, to a Column of Mercury, of the ſame Baſe, and one

Inch long; or that Air is 12000 times lighter than Mercury, and conſequently about 860 times lighter than Water.

If the Barometer be carried downwards, the Mercury will riſe, becauſe there will be more Air preſſing upon it: Thus I have known a Barometer, ſtand at 29,9 at the Bottom of a Coal-Pit 64 Fathom deep, when it ſtood at 29,51 Inches at the Top, which agrees pretty exactly with the Deſcent of the Mercury before mentioned, in going upwards.

The perpendicular Height of the Mercury in the Barometer (by Chap. 4. §. 6.) will be the ſame, if the Preſſure be the ſame in all Manner of Tubes, whether wide or narrow, crooked or ſtraight; upon which Principle, depends the Conſtruction of the Diagonal, Horizontal, Carteſian, and Pendent Barometers.

VI. Under this Head we may bring the Siphon, or
Fig. 8. Crane, which is generally a bended Tube, as A B C; and being firſt fill'd with Water, one End as A, is immers'd in a Veſſel containing Water, which will riſe up the Leg A B, and paſſing over the Top of the Siphon, will run out at the End C, ſo long as there is any Water left in the Veſſel, or till the Surface thereof in the Veſſel be of an equal Height with the End of the Siphon, where it runs out.

The Philoſophical Reaſon why the Siphon continues to run, is, Becauſe the Atmoſphere preſſes upon both Ends of the Tube, and keeps it full; then all the Water contain'd in the Tube, from the Top to the End C, will by its Weight tend towards C; and that which is contain'd in the other Leg, from the Top of the Siphon, to the Surface of the Water in the Veſſel, will tend the contrary Way: And therefore, (by Chap. 4. §. 6.) the Water will run out at C, ſo long as it is lower than the Surface thereof in the Veſſel.

'Tis evident, that this is the true Cauſe of the Siphon's running, becauſe, When a little Hole is made in the Tube, any where about the Top, the Water immediately ſtops; or if the Siphon be put under a Receiver, and the Air exhauſted, the Fluid in the Siphon will divide at the Top, and fall down in each Leg.

Hence Water may be made to run over any Hill, Houſe, or Wall, that is not above 33 Feet High; but if it be more (by Chap. 7. §. 3.) the Water will divide at the Top, and fall down in each Leg.

Other Fluids will riſe in the Siphon to a greater or leſs Height, according to their ſpecific Gravities; as Mercury will riſe only 30, or 31 Inches.

If a Siphon as b a c, be placed within a Veſſel, and one Leg, a c, paſſes thro' its Bottom, and Water be pour'd into this Veſſel, it will not run out till the Surface comes above the Top of the Siphon; but when it does, the Water will run down the Leg a c, which, being once fill'd, will continue to diſcharge the the Water at c, as long as there is any in the Veſſel. Fig 9.

From ſomething of this Kind, we can eaſily account for Ebbing and Flowing Wells; for, if I imagine Water to run gradually into this Veſſel, till the Surface comes to the Top of the Siphon, then if the Water runs out by the Siphon, faſter than it runs in, the Veſſel will become empty, and then the Siphon will ſtop till it is quite full again.

Theſe intermitting Springs may be alſo accounted for thus. Let W D B, repreſent the Side of a Hill, in which is a Cavity C; if from this Cavity there be a Paſſage or Vein running in the Direction A E W; then the Rains or Vapours falling off the Side of the Fig. 10.

Hill, will ſtrain thro' the Pores of the Earth, and fill the Cavity C; but when the Surface of the Water riſes to the Level of D C, the ſubterraneous Duct will be fill'd, and will act in the ſame Manner as a Siphon, till all the Water be run out of the Cavity; at which Time, the Fountain at W will ceaſe to flow, till the Cavity be full again.

VII. The *Fire-Engine* comes next in Order to be explain'd; but as it will be difficult to give a particular Deſcription of its ſeveral Parts, without Plates or Cuts, to repreſent thoſe Parts, I ſhall therefore, only explain the Principles upon which the Engine depends, and endeavour to make the moſt remarkable Parts of it as intelligible as poſſible: Therefore,

1. It is known, that the Atmoſphere preſſes upon the Surface of the Earth, with a Force equal to about 15 Pounds upon every Square-Inch.

2. That hot Steam is very elaſtic, and when it is cool'd by any Means, particularly by its being mix'd with cold Water, its Elaſticity is deſtroy'd, and conſequently the Steam reduced to Water again.

3. If a Veſſel be fill'd with hot Steam, and then clos'd up ſo as to keep out the external Air, and all other Fluids; when that Steam is by any Means cool'd, condens'd, or reduc'd to Water, that Water will fall to the Bottom of the Veſſel, and the Cavity of the Veſſel will be almoſt a perfect Vacuum.

4. When ever a Vacuum is made in any Veſſel, the Air by its Weight will endeavour to ruſh into it, or to drive in any Fluid, or other Body which will give Way to its Preſſure. This may be eaſily ſeen, if you ſtop cloſe the Bottom of a Syringe, and then draw up the Piſton, if it be ſo tight as to drive out all the Air before it, and leave a Vacuum in the Bottom of the

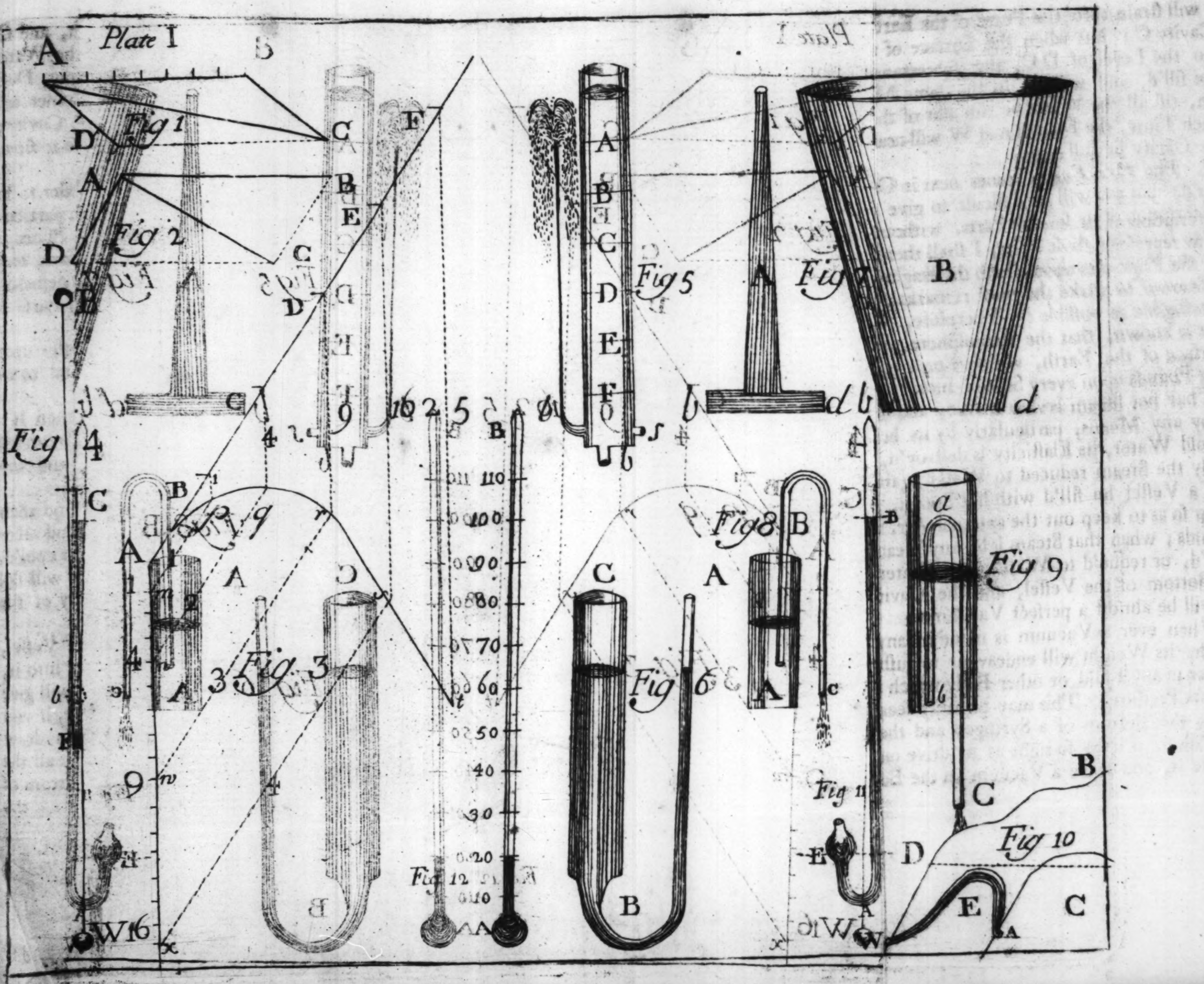

Plate I
Fig 1
Fig 2
Fig 3
Fig 4
Fig 5
Fig 6
Fig 7
Fig 8
Fig 9
Fig 10
Fig 11
Fig 12
A
B
C
D
E
F
a
b
c
d
W 16
110
100
90
80
70
60
50
40
30
20
10

the Syringe, the Piſton being let go, will be drove with a great Force.

5. The Force with which the Piſton is drove down, when there is a Vacuum under it, will be as the Square of the Diameter of the Syringe, as will appear to any one who conſiders the Cauſe of its Deſcent; and if it be one Inch Diameter, the Piſton will be driven down with a Force equal to about 12 Pounds.

Theſe are all the Principles, I think neceſſary to be premis'd, in order to underſtand the Machine itſelf, which conſiſts chiefly of 3 Parts, 1. A Boiler. 2. A Cylinder and Piſton. 3. A Beam, or Lever.

The *Boiler* is a large Veſſel, generally made of Iron or Copper, of various Shapes and Sizes, but commonly ſo big, that it will contain about 2000 Gallons.

The *Cylinder* is made about 40 Inches Diameter, and 10 or 11 Feet long, bor'd ſmooth on the inſide, and its Piſton fits it ſo tight, that little or no Water can get by.

Things being thus prepar'd, the Cylinder is plac'd with its Axis perpendicular to the Horizon, and the Shank of the Piſton is fix'd to one End of the Beam, which turns upon a Centre like a common Balance.

The Boiler is plac'd under the Cylinder, with a Communication between them, which can be open'd and ſhut occaſionally.

The Boiler is fill'd about half full of Water, and a ſtrong Fire made under it; then, if the Communication between the Boiler and the Cylinder be open'd, the Cylinder will be filled with hot Steam.

The Cylinder being thus fill'd, if the afore-ſaid Communication be ſhut, and a little cold Water thrown in amongſt the hot Steam, it will be condens'd, a

Vacuum will be made, and the Piſton will be preſs'd down by the Atmoſphere.

If the Cylinder be 42 Inches Diameter, the Piſton will be preſs'd down with a Force greater than 20000 Pounds, and will conſequently lift up that Weight at the oppoſite End of the Beam; and as it is fix'd to the Bucket of a Pump, if that Pump be 10 Inches Diameter, and 180 Yards long, all the Water contain'd in it will be lifted up.

This is upon a Suppoſition, that a perfect Vacuum is made in the Bottom of the Cylinder, which cannot be done by mixing Steam and Water together, but it is found experimentally, that a Cylinder 42 Inches Diameter, will work a Pump 10 Inches Diameter, and 100 Yards long; and hence we can find the Length and Diameter of a Pump, that will be work'd by any other Cylinder.

For the Convenience of ſuch as would make uſe of this Engine for raiſing Water, I have calculated a Table ſhewing the Diameter of a Pump, that will be work'd by any Cylinder from 36 to 44 Inches; and riſes Water from any Depth between 80 and 200 Yards.

THE

The TABLE.

	36	38	40	42	44
80	9.58	10.11	10.64	11.18	11.70
90	9.02	9.53	10.03	10.53	11.03
100	8.57	9.05	9,52	10.00	10.47
110	8,17	8.62	9.08	9.53	9.98
120	7.82	8.26	8.69	9.13	9.56
130	7.46	7.88	8.29	8.71	9.12
140	7.24	7.64	8.05	8.54	8.85
150	6.99	7.38	7.77	8.16	8.54
160	6.77	7.15	7.53	7.90	8.28
170	6.56	6.93	7.29	7.66	8.02
180	6.38	6.74	7.09	7.45	7.80
190	6.22	6.56	6.91	7.25	7.60
200	6.06	6.39	6.73	7.07	7.40

Find the Depth of your Mine in the firſt Column, and the Diameter of your Cylinder at the Top, and at their meeting in the Table, you find the Diameter of the Pump.

EXAMPLE.

If the Diameter of the Cylinder be 40 Inches, and the Depth of the Pit 110 Yards, then the Diameter of the Pump muſt be 9,08 Inches.

N. B. The Square of the Diameter of the Pump, will ſhew nearly how many Hogſheads of Water are diſcharg'd in 20 Minutes.

CHAP. X.

OPTICS;

OR,

The PROPERTIES of LIGHT.

I. LIGHT is an infinite Number of infinitely* ſmall Particles of Matter, flowing in right Lines from a luminous Body; as from a lighted Candle, there are continually flowing ſuch Particles of Matter, in all Manner of Directions; and thoſe Particles ſtriking upon our Eyes, excite in our Minds the Idea of Light.

II. When theſe ſmall Particles flowing from the Sun, or from a Candle, fall upon Bodies, and are thereby reflected to our Eyes, they excite in us the Idea of the Body they were laſt reflected from; and conſequently from every Point of a viſible Body, there are Particles of Light flowing in all Manner of Direction.

III. The Velocity with which the Particles of Light proceed from the Surface of Bodies, is ſo ſurprizingly great, as to paſs thro' above 10 Millions of Miles in a Minute: For, it is demonſtrable by the Eclipſes * of *Jupiter*'s Satellites, that they came from the Sun to the Earth, which is 81 Millions of Miles in about 7 Minutes.

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* By this Word, I mean nothing more, than that the Number and Smalneſs of the Particles of Light are paſt our Comprehenſion.

A Ray of Light is a continued Stream of theſe Particles, flowing from any viſible Body in a right Line.

IV. When a Ray of Light paſſes out of one Medium ‡ into another, it is refracted † towards the denſer Medium; and it is refracted more or leſs, as it falls more or leſs obliquely upon the refracting Surface, which divides the two Mediums.

This is prov'd by ſeveral Experiments.

1. Place a Baſon, or any other Veſſel, as A B E, where the Sun ſhines obliquely, and obſerve the Point e, where the Shadow of the Brim falls upon the Bottom of the Veſſel, then fill it with Water, and the Shadow will fall at E, which proves, that the Rays of Light falling obliquely on the Surface of the Water are refracted, or bended downwards, or towards the Water. Fig. 8.

2. Lay a ſtick over the Veſſel, and let the Sun's Rays be reflected into the Veſſel, perpendicular to the Surface of the Water, and the Shadow will fall

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* The Eclipſes of *Jupiter*'s Satellites, appear to us about 7 Minutes ſooner than they ought to do by Calculation, when *Jupiter* is neareſt to us; and about 7 Minutes later, when he is at the greateſt Diſtance from us; and the Difference between his greateſt and leaſt Diſtance, is equal to the Diameter of the Earth's Orbit, thro' which Light muſt paſs in 14 Minutes, or from the Sun to the Earth in 7 Minutes.

‡ A Medium in this Senſe, is any tranſparent Body, or that thro' which the Rays of Light can paſs; as Water, Glaſs, Diamond, Air; and a Vacuum, is ſometimes call'd a Medium.

† Refraction is only bending or breaking the Rays of Light, ſo as to turn them out of the Direction iu which they were moving, and to make them move in another.

upon the ſame Place, whether the Veſſel be empty or full; which proves, that the Rays of Light are not refracted, when they fall perpendicularly on the refracting Surface.

3. Put the End of a ſtraight Stick obliquely into a Veſſel of Water, and look upon it obliquely, it will appear bended at the Surface of the Water, in the ſame Manner as the Rays of Light are bended, only, in a contrary Direction.

V. The Rays of Light are as much refracted by paſſing out of Water into Air, as they are by paſſing out of Air into Water; but the Refraction is made the contrary Way: *e.g.* Suppoſe a Ray of Light to flow from the Point E, in the Direction E D, when it comes to D, the Surface of the Water, it will be refracted into the Line D C; as may be demonſtrated experimentally. Fig. 8.

VI. What has been ſaid of Water may be appli'd to any other tranſparent Body; only, the Refraction is greater in ſome than in others*; and therefore, from hence we may eaſily ſee, how the Rays will paſs thro' all Sorts of Glaſſes.

Glaſs may be ground into theſe 6 different Shapes.

1. A Plain-Glaſs, one that is ground plain on both Sides, and of equal Thickneſs in all its Parts.

2 A

Fig. 8. * The Angle C D P, contain'd between a Ray of Light, and a perpendicular to the refracting Surface, is call'd the Angle of Incidence; and the Angle E D R, contain'd between the ſame perpendicular, and the ſame Ray, after Refraction, is call'd, *Angle of Refraction.*

The Sine of the Angle of Incidence is to the Sine of the Angle of Refraction always in a given Ratio, *viz.* when a Ray of Light paſſes out of Air into Glaſs, as 3 to 2; out of Air into Water, as 4 to 3; out of Air into Diamond, as 5 to 2.

2. A Plano-Convex, one that is ground Plain on one Side, and Convex on the other.

3. A Double-Convex, one that is Convex on both Sides.

4. A Plano-Concave, one that is ground plain on one Side, and concave on the other.

5. A Double-Concave, one that is ground concave on both Sides.

6. A Miniſcus, one that is ground concave on one Side, and convex on the other.

VII. A Ray of Light paſſing thro' a plain Glaſs, will go out of the Glaſs in the ſame Direction, tho' not preciſely in the ſame right Line, for a Ray of Light R D, falling obliquely upon the Surface of the Glaſs A D, will (by Chap. 10. §. 4.) be refracted towards the Glaſs into the Direction D E; but when it comes to E, it will (by Chap. 10. §. 5. and 6.) be as much refracted the contraty Way; ſo that, E F, will be parallel to R D. Fig. 9.

VIII. If Parallel Rays of Light, as R D, S T, paſs thro' a Convex-Glaſs, they will be gather'd into a Point behind it: For the Ray R D, which falls perpendicularly upon the middle of the Glaſs, will go thro' it, without ſuffering any Refraction; but the Ray S T, which goes thro' the Side of the Glaſs, falls obliquely upon its Surface, and therefore will be refracted; ſo that after it comes out of the Glaſs, it will meet the other in F; and the nearer the Side of the Glaſs, the Ray S T, paſſes, the more obliquely it will fall, and will be the more refracted; and therefore, all the Rays which fall upon the Glaſs will be collected in the Point F, call'd the principal Focus ‡. Fig. 14.

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‡ The Diſtance from the Glaſs to the Focus, is call'd, *The Focal Diſtance*; which, in a Plano-Convex, is equal to twice the Radius of the

Hence we ſee, why a Convex-Glaſs burns by the Sun's Rays paſſing thro' it.

Fig. 10. IX. If a Ray of Light, as R D, paſs obliquely thro' a Convex-Glaſs, it will go forward in the ſame Manner, as if it had paſs'd thro' a plain Glaſs; that is, it will go out of the Glaſs in the ſame Direction with which it enter'd; for it will be refracted at the Points D and E, in the ſame Manner, as if it had paſs'd thro' the plain Surfaces c d and a b, which are parallel to each other, as might be eaſily demonſtrated. But if a Ray, as R B, or R P, paſs thro' the Side of the Glaſs, it will be refracted, ſo as to meet the other in the Point F, as will be eaſily ſeen, from Chap. 10. § 4. Therefore, all the Rays which flow from the Point R, meet again at F.

X. The Rays which flow from any Object thro' a Convex-Glaſs, will paint an inverted Picture thereof, upon any white Body placed in the Focus.

This may be eaſily demonſtrated experimentally, and the Reaſon we ſhall ſee plainly, from the laſt Propoſition.

Fig. 12. Let L N, be a Convex-Glaſs, and A K the Object, the Rays which flow from the Point A ‡, will paſs thro' the Glaſs, and meet again at a, in the ſame Manner, as the Rays which flow from R, meet again Fig. 10. at F; alſo the Rays which flow from the Point K, will paſs thro' the Glaſs, and meet each other again at

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the Convex-Surface; and in a Glaſs equally Convex on both Sides, it is one the Radius of either Surface: but if a Glaſs be more Convex on one Side, than another; the Rule for finding the Focus is this; Divide the double Product of the Radii, by their Sum, and the Quotient will be the Focal Diſtance ſought.

‡ Rays will flow from the Point A, in all Manner of Directions; but none are here repreſented, but ſuch as paſs thro' the Glaſs.

at k[*]; for the ſame Reaſon, the Rays which flow from any of the intermediate Points, B, C, D, E, F, will meet each other again, at their reſpective intermediate Points, b, c, d, e, f; conſequently, if a Sheet of white Paper, or any other white Body be placed at k a, to receive theſe Rays, there will be painted upon it an inverted Picture of the Object, A K.

XI. If the Object A K, be brought nearer to the Glaſs L N, the Picture k a, will be remov'd to a greater Diſtance[‡]; for the Rays which flow from any ſingle Point, as A, will diverge or ſpread more as they fall upon the Glaſs, and therefore, cannot be ſo ſoon gather'd together behind it. If the Diſtance of the Object from the Glaſs, be equal to the Diſtance of the principal Focus of that Glaſs, the Rays which flow from one ſingle Point of the Object, will be ſo refracted by paſſing thro' the Glaſs, that they will go out of it parallel to each other; and therefore, there will be no Picture made behind the Glaſs.

XII. The Picture which is made by a Convex-Glaſs will be as much bigger or leſs than the Object, as its Diſtance from the Glaſs is more or leſs, than that of the Object, *viz*, as D I, is to I d, ſo is A K, to k a.

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[*] The Rays which flow from a ſingle Point of an Object, and by paſſing thro' a Convex-Glaſs, are gathered to another Point, are call'd, *A Pencil of Rays:* Thus the Rays A o a, A q a, *&c.* conſtitute a Pencil, flowing from the Point A; and the middle Ray A I a, is call'd, *The Axis of the Pencil,* which, in Effect, is a ſight Line.

[‡] The Diſtance I d of the Picture from the Glaſs may be found, if the Diſtance of the principal Focus deſcrib'd, § 8 and the Diſtance of the Object be known, by this Rule; Multiply the Diſtance of the principal Focus, by the Diſtance of the Object, and divide the Product by their Difference.

XIII. Having deſcrib'd how the Rays of Light paſs thro' Convex-Glaſſes, it will be eaſy to ſee, how they will be affected by paſſing thro' the Humours of the Eye ‡; for as the ſeveral Rays which flow from a ſingle Point of an Object, thro' a Convex-Glaſs, are collected into a Point on the other Side; ſo the Humours of the Eye, in general, and the Cryſtalline Humour in particular, being the ſame as a Convex-Glaſs, the Rays which flow from the ſeveral Points of an Object thro' thoſe Humours, will meet each other again at ſo many reſpective Points, at the Bottom of the Eye, upon a tender thin Skin call the Retina †; and therefore, there will be panted upon the Retina an inverted Picture of all Objects, that are plac'd before the Eye.

This may be demonſtrated experimentally. Take a Bullock's Eye while it is freſh, and cut away the Coats or Skins which cover the vitreous Humour on the back Part; then place a Piece of white Paper upon that Part, and hold the Eye towards a Candle, or any bright Object, ſo that the Rays which flow from it, may paſs thro' the Pupil *, and you will find an inverted Picture of the Object upon the Paper.

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‡ The Eye when taken out of the Head is nearly Globular; a Section of it is repreſen ted by g B C d. ig. 13. It contains 3 Humours, which are tranſparent. 1. The Space a d g p on the fore Part of the Eye is fill'd with a Fluid like Water; and therefore call'd the *Aqueous Humour*. 2. The Cryſtalline Humour is repreſented by a r p, being in the Shape of a double Convex Glaſs, and about the Conſiſtence of a hard Jelly. 3. The Space r B C a is fill'd with the viterous Humour, which is about the Conſiſtence of the white of an Egg. Theſe 3 Humonrs are incloſ'd by 3 Coats, or Skins; that which covers the Eye on the fore Part g d, is call'd, *Tunica Cornea*, and is tranſparent and pretty thick.

† The Retina is only the Fibres of the Optic Nerve expanded, ſo as to cover the Bottom of the Eye all over on the inſide, immediately behind the vitreous Humour.

The Progreſs of the Rays, thro' the Humours of the Eye, is repreſented by Fig. 13, in which O B repreſents the Object, and O p o, B p b, the Rays flowing from the Points O and B, and meeting again at o, b.

Cor. 1. Hence the Rays which flow from any ſingle Point of an Object, muſt fall upon the Eye either parallel, or diverging a little; for otherways, that Object cannot be ſeen diſtinctly.

Cor. 2. The nearer the Object is to the Eye, the greater the Picture will be, by Chap. 10, §. 12; but if the Object be brought too near the Eye, the Picture on the Bottom will not be diſtinct †, by the latter Part of §. 11. And hence, we know the Reaſon, why we cannot ſee an Object when it is placed within an Inch or two of the Eye.

If the Humours of the Eye were immoveable, we could ſee an Object diſtinctly, at one Diſtance

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* The Aqueous Humour is almoſt divided into two Parts by a Membrance; but thro' the middle of it at p, is a Hole call'd, *The Pupil*; it is that little black Spot in the middle of the Eye, which is vulgarly call'd, *The Sight of the Eye.*

This Pupil enlarges, when we go into a dark Place, and contracts in a light one; as may be eaſily prov'd experimentally.

In ſome Animals this Power of enlarging and contracting the Pupil, is much greater than in others, as in Cats, Owls, and ſuch as can ſee in the Night. And hence we find the Reaſon of the Sun-blind Eye.

† The limit of diſtinct Viſion in moſt Eyes is at the Diſtance of 5, or 6 Inches; but ſuch as have either the Cryſtalline Humour, or the *Tunica Cornea*, more convex than ordinary, can ſee diſtinctly at a leſs Diſtance, and are ſaid to be purblind or ſhort ſighted, and in order to ſee diſtant Objects diſtinctly, are oblig'd to make uſe of a Concave-Glaſs plac'd before the Eye. On the contrary, if the Cryſtalline Humour, or the *Tunica Cornea*, be too flat, a Convex-Glaſs muſt be plac'd before the Eye, as is the caſe in moſt old Eyes.

only, by §. 11. But by Experience, we know, that Objects appear to us diſtinctly, at different Diſtances; and therefore, we have a Power of altering the Poſitions, or Shapes of ſome of the Humours.

The Refraction of Rays being explain'd, Reflection comes next to be conſider'd.

XIV. When a Ray of Light falls upon an Opake * Body, Part of it is reflected, and Part enters the Body and is loſt in its Pores: When a Ray falls upon a tranſparent Body, Part is reflected, and Part enters the Body, and is refracted, according to the Laws before explain'd.

When a Body (as a Piece of Metal) is ground ſmooth, and poliſh'd, ſo as to reflect the Rays of Light regularly, it is call'd a *Mirror*.

XV. Whenever a Ray of Light is reflected, this Law, is obſerv'd *viz.* the Angle of Incidence ‡ is equal to the Angle of Reflection: *e.g.* Suppoſe a Ray Fig. 2. D P, falls upon the ſmooth Surface B N, it will be reflected into the Line P E, and if it falls perpendicular to the Surface, it will be reflected back in the ſame Line, as A B.

Cor. 1. Hence we ſee the Reaſon, why an Object ſeen by a plain Mirror, appears as far behind the Mirror, as it really is on this Side; for the Rays of Fig. 3. Light, which flow from the Point O, of the Object O B, will fall upon the Mirror M R, and be reflected to the Eye at E; and therefore, will enter the Eye as if they really flow'd from o: For the ſame Reaſon, the Rays which flow from the Point B, in order to enter the Eye at E, muſt fall upon the Mirror at F, and ſo the Point B will appear in the Continuation of the Lines E F, as if it was at b; therefore the Object O B, will appear at o b.

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* An Opake Body, is that which does not tranſmit the Rays of Light.

‡ The Angle of Incidence, is the Angle contain'd between a Ray of Light, and a perpendicular to the reflecting Surface at the Point of Reflection; and the Angle of Reflection, is the Angle contain'd between the ſame perpendicular, and the reflected Ray.

The ſame Explanation will ſerve for Fig. 4. and 5. the one ſhewing why an Object ſeen in a Concave-Mirror appears bigger than it really is; and the other ſhewing why an Object ſeen in a Convex-Mirror appears leſs.

Cor. 2. If parallel Rays, as, a b, a b, fall upon a Concave-Mirror M R, they will be reflected into a Point F, call'd the *Principal Focus* †. This is the Reaſon why the Sun's Rays, reflected from a Concave-Mirror, burn with ſuch incredible Force in that Point, Fig. 6.

XVI. If an Object be plac'd at a greater Diſtance from a Concave-Mirror, than the principal Focus, the Rays which flow from it, being reflected by a Concave-Mirror, will make an inverted Picture of the Object upon any white Body plac'd to receive them.

Fig. 8. Let M R be a Concave-Mirror, and O B the Object; the Rays which flow from the Point O, will fall upon the Mirror, and every one making the Angle of Reflection equal to the Angle of Incidence, they will meet each other again at C; for the ſame Reaſon, the Rays flowing from the Point B, will meet again at P, ſo that C P will be an inverted Picture of O B.

If an Eye be placed in the Continuation of the Rays M P, it will receive thoſe Rays as if they flow'd from a real a real Object at P C; and hence we ſee the Reaſon of the odd Phænomenon exhibited by a Concave-Mirror, of a Body ſuſpended in the Air between the Eye and the Mirror.

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† The Diſtance from the Mirror to the Point F, is call'd *The Focal Diſtance*; which, in this Caſe, is equal to half the Radius of the Concave-Surface.

XVII. The nearer the Object O B, is to the principal Focus, the greater is the Diſtance of the Picture P C ‡, (and the contrary) for the Rays will diverge more as they fall upon the Mirror. What was ſaid of the Picture made by a Convex-Glaſs, in §. 11 and 12 will hold good of that which is made by a Concave-Mirror.

XVIII. We have before prov'd, that the Rays of Light are refracted, when they paſs obliquely thro' different Mediums; but we come now to prove, that ſome Rays of Light are more refracted than others; and that according as they are differently refracted, they excite in our Minds, Ideas of different Colours.

Exper. Let the Sun ſhine into a dark Chamber, Fig. 15. thro' a ſmall Hole, as F. Place before the Hole a Glaſs-Priſm, in ſuch a Manner, that the Rays F A, may fall obliquely upon its Surface, and they will ſuffer different Refractions by paſſing thro' the Priſm: So, that inſtead of going out of it all in one Direction, they will go in the different Directions repreſented by the Lines A R, A O, A Y, &c. and falling upon the oppoſite Side of the Room, or upon a white Paper, will paint upon it a Series of moſt beautiful, lively Colours, in this order, *viz.* thoſe which are leaſt refracted by the Priſm, and therefore, go in the Direction of the Line A R, will be of a very bright and intenſe Red; the next going in the Direction A O, will be of an Orange Colour; then Yellow, Green, Blue, Indico: And laſtly, Thoſe Rays which are moſt refracted, excite in us the Idea of a ſoft Violet Colour.

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‡ If the Radius of the Concavity, and the Diſtance of the Object O B from the Mirror be known, the Diſtance of the Picture from the Mirror is found by this Rule; Divide the Product of the Diſtance and Radius, by double the Diſtance made leſs by the Radius, and the Quotient is the Diſtance required.

XIX. There are different Degrees in all theſe Colours: Thus, the Red degenerates by Degrees into on Orange, and the Orange into a Yellow, the Yellow into a Green, &c.

There is not an equal Quantity of Rays belonging to each of theſe Colours; but if the Oblong-Image, or Series of Colours R V, be divided into 360 equal Parts, Sir *Iſaac Newton* found, that the Red took up 45 of them; The Orange 27; The Yellow 48; The Green 60; The Blue 60; The Indico 40; And the Violet 80.

XX. If all theſe Colours be blended together again, they will make a white, as is prov'd thus.

Having divided the Rays of the Sun by a Priſm into the Colours before mention'd, receive them upon a Convex-Glaſs, as L M, which will refract them in ſuch a Manner, that they will croſs each other at D; and, if a white Paper, c d, be placed there to receive them, we ſhall find, they will excite the Idea of a lively ſtrong white: But if the Paper be placed farther from the Glaſs, as at e f, the different Colours will appear again in a contrary Order. Fig. 16.

If any one of the Colours be ſtop'd before they meet at D, The white will be imperfect, and inclining to Violet or Red, according as the Red or Violet Rays are ſtop'd.

XXI. When a Ray of Light is once ſeparated from the reſt, it cannot be divided into any other

ther Colours, tho' it be never ſo often reflected or refracted.

XXII. As white is a Compoſition of all Colours, ſo black is a Privation of all, and therefore, properly no Colour.

XXIII. Any one of theſe Colours, except Red and Violet, may be made by mixing together the two contiguous Priſmatic Colours: Thus Yellow is made by mixing in a due Proportion Orange and Green; And Green may be made by a Mixture of Yellow and Blue.

XXIV. All Bodies appear of that Colour, whoſe Rays they reflect moſt; as a Body appears Red when it reflects moſt of the red-making Rays, and abſorbs the Reſt; A Blue or Green Body reflects the blue or green-making Rays, and ſo of the Reſt.

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CHAP. XI.

Of Optical INSTRUMENTS.

I. THE *Camera Obſcura* is made by a Convex-Glaſs, of 6, 8 or 10 Feet Focal-Diſtance, and about 3 Inches Diameter, plac'd in a Hole of the Window-Shutter; then, if the Room be made ſo cloſe, that no Light can enter but what comes thro' the Glaſs, all the Objects (as Fields, Trees, Flowers, Cattle, *&c.*) on the out Side, will be painted inverted upon a white Paper, or Sheet, plac'd in the Focus of the Glaſs, and will afford a moſt beautiful and perfect Piece of Perſpective, or Landſcape of whatever is before the Glaſs; eſpecially, if the Window be oppoſite to the Sun, and it ſhine ſtrongly upon the Objects.

II. The ſingle Microſcope, is only a ſmall Convex-Glaſs, as L, the Object a b, is placed in its Focus, and the Eye at the ſame Diſtance on the other Side; then it is plain by the Figure, that the Rays which flow from the Extremities of the Object a and b, will enter the Eye in the Lines c E, and d E, and conſequently will appear under a greater Angle than if there had been no Glaſs ‡. Fig. 11,

M III. The

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‡ To find how much this Glaſs magnifies, divide the leaſt Diſtance, at which an Object can be diſtinctly ſeen with the naked Eye, by the Focal-Diſtance of the Glaſs, and the Quotient will ſhew nearly, how much the Glaſs magnifies.

III. The Compound Microſcope is generally made with three Glaſſes, placed as in Fig. 17. F H is the Object Glaſs, of about half an Inch, or an Inch Focus, A B, and D C, are the two Eye-Glaſſes placed ſometimes cloſe together, and ſometimes an Inch or two aſunder. m n is a ſmall Object, plac'd at a little greater Diſtance from the Lines F H than its principal Focus; ſo that the Rays flowing from the Object thro' the Lens, will (by Chap. 10. §. 10 make an inverted Picture M N; which (by Chap. 10. §. 12.) will be as much bigger than the Object, as its Diſtance from the Lens is greater than that of the Object; and the Eye-Glaſſes anſwer the End of a ſingle Microſcope, for looking upon the inverted Picture.

By the Figure it will be eaſily obſerved, that the Rays which flow from m n, the Extremities of the Object, will enter the Eye in the Direction of the Lines A E, and B E; and therefore, the Object will be ſeen under the Angle A E B, which is much greater than that in which it would be ſeen by the naked Eye; and the Rays which flow from any ſingle Point of the Object, as m, will enter the Eye parallel to each other; and therefore, will be ſeen diſtinctly by Chap. 10. §. 13. *Cor.* 1.

IV. The Solar-Microſcope is made thus;

Having procur'd a very dark Room, let a round Hole be made in the Window-Shutter, about 3 Inches Diameter, ſo that the Sun may caſt a Cylinder of Rays into the Room: In this Hole, place the End of a Tube, containing two Glaſſes and an Object *viz.*
Fig. 18. 1. A Convex Glaſs a a, of about 2 Inches Diameter, and 3 Inches Focal-Diſtance, is to be placed at that End of the Tube, which is put into the Hole. 2. The Object o b, being put upon a Piece of Glaſs, or between two Pieces of Glaſs, is placed about

about 2 Inches and a half from the Glaſs a a. 3. A little more than an Inch from this Object, is placed a ſmall Glaſs d e, about one Inch Focus, and half an Inch Diameter.

Things being thus prepar'd, the Rays which flow from the Object o b, will make a large inverted Picture at O B, (by Chap. 10. §. 10 and 12.) This Picture being receiv'd upon a white Paper, will repreſent the Object o b, moſt beautifully and prodigiouſly magnified.

N. B. The Tube muſt be ſo placed, that the Sun's Rays R a, may flow thro' the Glaſs a a, and caſt a ſtrong Light upon the Object o b, or elſe thoſe Rays muſt be reflected thro' the Glaſs a a, by a plain Mirror, as a Piece of Looking-Glaſs; which, I think, is the better Way, becauſe the Picture may be kept in the ſame Place, ſo as to be eaſily drawn upon the Paper.

V. The Conſtruction of the common Refracting-Teleſcope, is repreſented by Fig. 19. In which A is the Object-Glaſs; its Focal-Diſtance A f, from one to 100 Feet. b, c, d, are three equal Eye-Glaſſes; Focal-Diſtance from one to ten Inches.

The Glaſſes being thus prepar'd, let them be plac'd in a Tube, in ſuch a Manner, that the Diſtance between any two, may be equal to the Sum of their Focal-Diſtances, as in the Figure: And the Eye muſt be plac'd at E, one Focal-Diſtance of any of the Eye-Glaſſes from the outermoſt one, d; Then it is plain, that the Rays flowing from any vaſtly diſtant Object, thro the Glaſs A, will make an inverted Picture of it at f, and the Eye-Glaſs b being plac'd its Focal-Diſtance from f, and the Eye again at e, the ſame Diſtance from b, the Picture will be ſeen diſtinctly, but inverted; ſo that to make it appear erect, two other Glaſses c d, are made uſe of as before deſcrib'd.

The Line m A, repreſents the Axis of a Pencil of Rays flowing from the Top of the Object; and n A, the Axis of one flowing from the Bottom: And when they enter the Eye either at e, or E, 'tis plain, they converge much more, than they did before their Entrance into the Glaſs; and therefore, the Object will be ſeen under a greater Angle *: But the Rays, n A, p q, flowing from the ſame Point of a diſtant Object, will enter the Eye at e, or E, parallel to each other, and conſequently the Object will be ſeen diſtinctly, by Chap. 10. §. 13. *Cor.* 1.

IV. In the Reflecting-Teleſcope, a Concave-Mirror is made uſe of inſtead of a Convex-Glaſs.

The Picture which is made by a Convex-Glaſs, is always ting'd a little with Colours about the Edge; the Reaſon of which is plain, from Chap. 10. §. 18. But the Picture made by a Concave-Mirror, never is ting'd with Colours; and therefore, the Reflecting-Teleſcope is better than the refracting one, ſo long as the Mirrors are kept clean.

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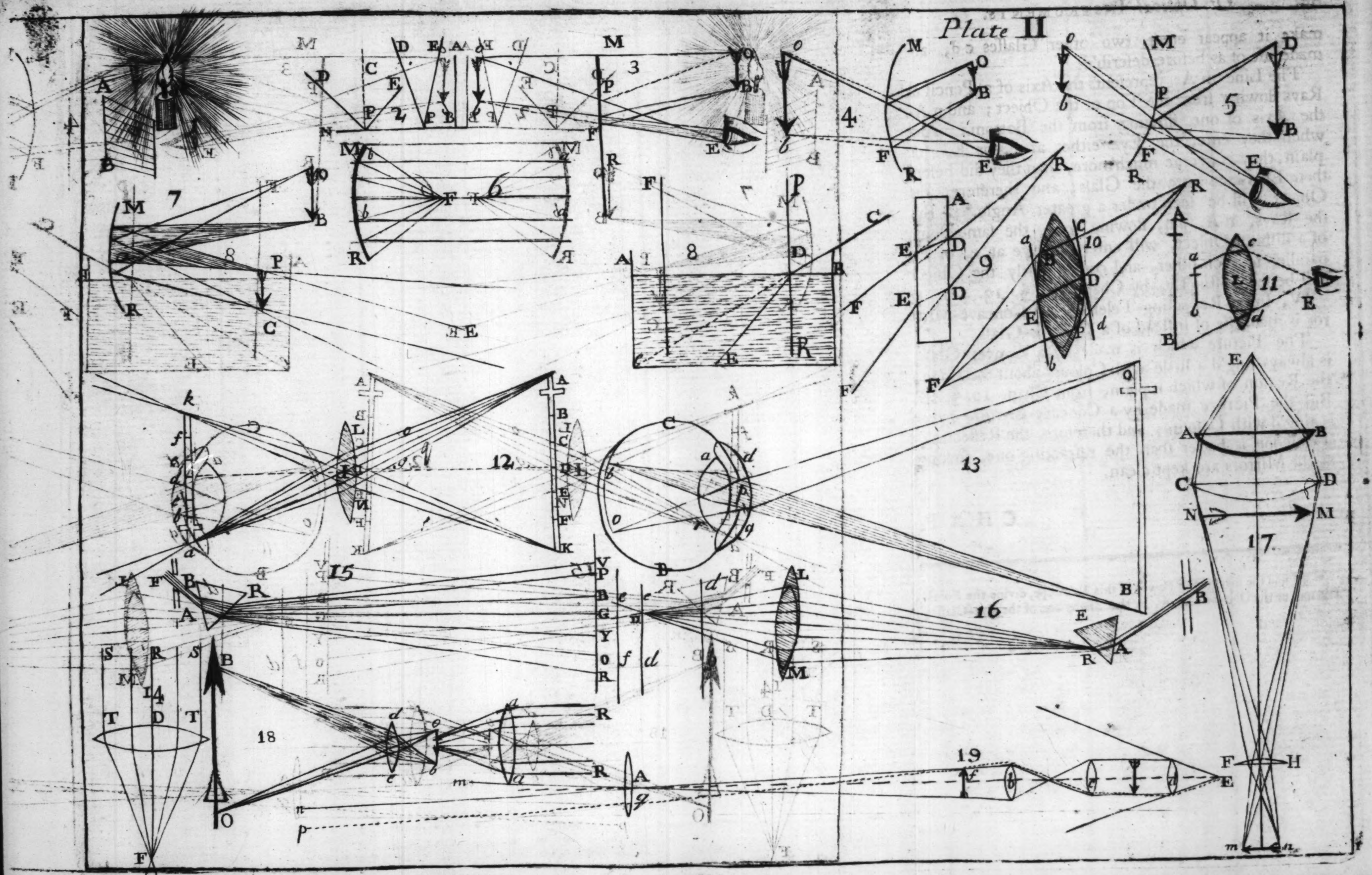
* To find the magnifying Power of this Teleſcope, divide the Focal-Diſtance of the Object-Glaſs A, by that of any one of the Eye-Glaſſes.

Plate II



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CHAP. XII.

Of the SOLAR-SYSTEM.

I. THE *Sun*, together with the *Planets* * and *Comets* ‡, which move round him, form what is call'd, *The Solar-Syſtem.*

The Primary-Planets revolve round the Sun, at different Diſtances; but almoſt all in one Plain, call'd, *The Ecliptic* †.

II. The Orbits of the Planets round the Sun, are repreſented by Fig. 1. Plate 3. in which, s repreſents the *Sun* ; a a the Orbit of the Planet *Mercury*; bb, that of *Venus* ; c c the Orbit of the *Earth*; d d that of *Mars* ; e e, that of *Jupiter* ; and laſtly, A B C, the Orbit, or Path of *Saturn.*

Behind the Orbit of *Saturn*, there are no other Bodies that we know of, except *Comets*, till we come to the fix'd *Stars.*

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* The Planets are Opake and dark Bodies, but the Sun ſhining upon them, they reflect the Rays back to the Earth, and ſo they appear to us to ſhine, as if they were Bodies of Fire.

‡ Comets are dark Spherical Bodies, like the Planets, and revolve round the the Sun in the ſame Manner, only their Orbits are very Excentric.

† The Ecliptic is that Plain, in which the Earth moves round the Sun, or it is the Plain of that Circle, in which the Sun appears to move amongſt the fix'd Stars.

The Surface of the Paper, where the Solar-Syſtem is drawn, Plate 3, repreſents the Plain of the Ecliptick.

III. The Planets revolve round the Sun from Weſt to Eaſt, or in the Direction A B C.

IV. The Secondary-Planets, are thoſe which revolve round the Primary, in the ſame Manner, as the Primary ones do round the Sun; of theſe the *Earth* has one, *viz.* the *Moon*; *Saturn* has five; And *Jupiter* four; call'd alſo, Their *Satellites*, or *Attendants.*

N. B. The Orbits of the Secondary-Planets, are drawn (in Fig. 1. Plate 3.) 10 times bigger than what they ought to be, in Proportion to the Orbits of the Primary-Planets.

V. The Dimenſions, Motions, Magnitudes, *&c.* of the Planets both Primary and Secondary, are repreſented by the Table, Page 92.

The Names of the Primary-Planets, *viz. Saturn, Jupiter*, &c. are ſhewn at the Head of the Table, together with the *Sun* and *Moon*.

VI. The firſt Line ſhews the Periods of the Planets; that is, the Times they take up in going once round the Sun, or the Centre of their reſpective Orbits; for Example, *Saturn* goes round the Sun in 29 Years, 167 Days. *Jupiter* in 11 Years, 315 Days. The *Moon* goes round the Earth in 27 Days, 7 Hours, 43 Minutes, *&c.*

The Period of a Planet is found by obſerving the Time it takes up, in going from a fix'd Star, and returning to it again.

VII. The next Line ſhews the Times of their Diurnal Revolutions; that is, the Times they take up in turning once round their reſpective Axes; *e. g.* *Saturn* is not known. *Jupiter* turns round his Axis in 9 Hours, 56 Minutes; and ſo of the reſt.

The Diurnal Revolution of a Planet, is found by obſerving the Motion of the Spots, which are found upon its Surface; as for inſtance, If we look upon the Sun with a Teleſcope, we ſhall ſee little black Spots upon its Disk ‡, or Surface, which always appear to move from Eaſt to Weſt, and to come to the ſame Poſition again in 25 Days 6 Hours.

VIII. The 3*d* Line ſhews the mean or middle Diſtance from the Sun in Miles; *e. g. Saturn* is 777 Millions of Miles from the Sun; *Jupiter* is 424 Millions; And ſo of the reſt, as in the Table.

The Methods made uſe of to diſcover the Diſtances of the Planets are ſo many, and the practical Part ſo difficult, that I ſhall not trouble my Reader with their Deſcription, but only obſerve in general;

That whenever the Diſtance from the Sun, to any one of the Planets is found, the Diſtance of the reſt may be found, by the famous Propoſition, firſt diſcover'd by the ingenious *Kepler*, and demonſtrated by the immortal Sir *Iſaac Newton*; *viz.* The Squares of the Periodical Times of the Planets round the Sun, are one to another, as the Cubes of their reſpective Diſtances from the Sun. The ſame Law is obſerv'd by the Secondary-Planets, in their Motions round their Primary.

From many Obſervations, made by different Perſons, in different Parts of the World, Aſtronomers have moſtly agreed, that the Diſtance of the Earth from the Sun is 81 Millions of Miles; and from this Suppoſition, the reſt are calculated as above.

The Diſtance of the Moon from the Earth, is pretty certainly known to be, 240000 Miles.

In the Year 1761, on the 26 of *May*, about 6 in the Morning, The Planet *Venus* will paſs between the

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‡ A Word us'd by Aſtronomers to ſignify the apparent flat Surface of the Sun, Moon, or Planets. When it is conſider'd as a Plain, it is divided into 12 equal Parts, call'd, *Digits*.

Sun and the Earth; at which Time, the Diſtance of the Sun may be pretty exactly known, and the Dimenſions of the Heavens more accuratly determin'd than has hitherto been done.

The Diſtance of the Planets from the Sun, or from one another, being expreſs'd by Numbers, does not convey a true Idea of thoſe immenſe Diſtances; for which Reaſon, Aſtronomers often have recourſe to other Methods: Suppoſe therefore, a Body was to be projected from the Sun, and to continue moving with the ſame Velocity, that a 24 Pounder does out of the Mouth of a Cannon, it would fly to *Mercury* in 7 Years, 221 Days; to *Venus* in 14 Years, 8 Days; to the *Earth* in 19 Years, 91 Days, 18 Hours; to *Mars* in 29 Years, 85 Days; to *Jupiter* in 100 Years, 280 Days; to *Saturn* in 184 Years, 240 Days; to the fix'd *Stars* in about 7600000 Years.

Theſe Numbers are eaſily calculated, upon a Suppoſition, that a Ball goes 8 Miles in a minute, as it does very near.

The next Line ſhews the Diameters of the Planets in Miles, of which *Saturn* is 93450 Miles; *Jupiter* 130600 Miles, *&c.*

The Diameter of the Planets is calculated from their apparent Diameters and Diſtances; for, if the Diſtance of any Globe, and its apparent Diameter be known, the real Diameter may be found by the known Rules of Trigonometry.

The 5*th* Line ſhews the Proportion of Bulk, or Bigneſs compar'd with the Earth; *e. g. Saturn* is 161 times as big as the Earth; *Jupiter* is 4400 times as big as the Earth; and ſo of the reſt.

Theſe Numbers are calculated from the laſt, thus, divide the Cube of the Diameter of any Planet, by the Cube of the Earth's Diameter, and the Quotient ſhews how much that Planet is greater than the Earth: For the Magnitudes of Globes are as the Cubes of the Diameters.

XI. The next Line ſhews the Quantity of Matter compar'd with the Earth; for Inſtance, *Saturn* contains 126 times as much Matter as the Earth; *Jupiter* 827, *&c.*

The Quantity of Matter in a Planet is known by its Attraction ‡; for all Bodies attract at equal Diſtances, with a Force proportionable to the Quantity of Matter they contain.

If the Quantities of Matter in the Planets, be divided by their Bulks, the Quotients will be one to another, as the Denſities of the Planets; therefore, from the two laſt Lines in the Table, the Denſities of the Planets are as theſe Numbers; *viz. Saturn* 0,72; *Jupiter* 0,188; The *Earth* 1; The *Sun* 0,26; *Moon* 1,25. Whence the *Moon* is the moſt denſe Body, and *Jupiter* the leaſt denſe of all the Planets.

XII. The Gravity on the Surface of a Planet, is the Tendency of a Body to the Centre of the Planet, when placed upon its Surface. The Force of this Tendency in the Table, is compar'd with the Earth; for

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‡ The Attractions of the Planets, are found by the Motions of their Secondary Planets; for it is demonſtrated by Sir *Iſaac Newton*, That if a Body revolves round another, towards which it is continually impell'd, or attracted, (the Diſtance remaining the ſame) the Squares of the Perodical Times will be inverſely as the attracting Force; but the Squares of the Perodical Times, are directly as the Cubes of the Diſtances, by §. 8. Therefore, if the Cubes of the Diſtances of the Planets, both Primary and Secondary, be divided by the Squares of the Perodical Times, the Qnotients will be as the Quantities of Matter in the Bodies, round which the others revolve; and becauſe *Mars*, *Venus*, and *Mercury*, have no Sceondary Planets revolving round them, their Quantities of Matter cannot be known.

Inſtance, Suppoſe a Body, as a Pound of Lead, was plac'd upon the Surface of *Saturn*, it would be attracted by him, with a Force expreſs'd by 0,92; that is, with 92 100*th* Parts of the Force it is attracted by the Earth, &c.

XIII. The next Line ſhews the Inclinations of their Axes; that is, how much their Axes are leaning from a perpendicular to the Plain of the Ecliptic; this is meaſur'd in Degrees and Minutes as before.

N. B. The Inclination of the Earth's Axis, (being 23° 19′) cauſes thoſe Viciſſitudes of Seaſons, which we on the Surface of the Earth have every Year, as is eaſily, and plainly ſhewn by the Orrery; and the greater is the Inclination of a Planet's Axis, the greater will be the Alteration of Seaſons in that Planet. Whence you'll obſerve that in *Jupiter* and *Mars*, there will be little or no Alteration, but always equal Day and Night.

XIV. The Orbits of the Planets, are thoſe Paths which they deſcribe by their Motions round the Sun; theſe Orbits are not all in one Plain, but are variouſly inclin'd to one another, and to the Plain of the Ecliptic, or the Earth's Orbit.

The Quantity of this Inclination is ſet down in the 8*th* Line; *e. g. Saturn*'s Orbit is inclin'd to the Plain of the Ecliptic 2 Degrees, 30 Minutes [‡]; *Jupiter*'s one Degree, 20 Minutes, &c.

[‡] When a little Cypher is put above a Number, it ſignifies Degrees, and a little Scratch, Minutes, thus 2° 30′ ſignifies 2 Degrees, 30 Minutes.

Every Circle, whether great or ſmall, is ſuppos'd to be divided into 360 equal Parts, call'd, *Degrees*, and every Degree into 60 Minutes, every Minute into 60 Seconds, &c.

XVI. The nearer any Body is to the Sun, the more it muſt be heated by it; and the Light and Heat which any Body receives from the Sun, muſt be inverſely as the Square of its Diſtance from it, as is evident upon the leaſt Conſideration; from which Principle, I have here calculated the Proportions of the Light and Heat, which the Planets receive from the Sun, in Compariſon of the Earth; as *Saturn* has 100*th* Part of the Light and Heat the Earth has; *Jupiter* one 28*th* Part, *&c.*

Here we ſuppoſe, that Heat is inſeparable from Light; but by many Obſervations, we find, there is ſomething in the Nature of Heat, which is not well underſtood, and that there may be Light without Heat: Thus, we find ſome Places, particularly the Tops of ſome Mountains, near the Equator, where the Sun's Rays are very bright and glaring, and yet the Air is extreamly cold: And again, other Places, of a conſiderable Latitude, where the Air is tolerably Warm.

If Heat does not depend upon the Sun's Rays, the Planets may all be of the ſame Heat with the Earth; ſo as to be habitable by ſuch Animals as are on the Earth.

If we know the Diameters of the Orbits of the Planets, and the Times they take up in compleating their Periods, it will be eaſy to calculate how faſt the Planets move; which I have here done, and ſet down in the Title of Velocities, Miles an Hour; for Example, *Saturn* runs thro' 19000 Miles in an Hour; *Jupiter* 25400; The *Earth* 58050, *&c.*

The Velocities of the Planets, are inverſly as the Square-Roots of their Diſtances from the Sun, as might be prov'd from §. 8. from which Principle, the foregoing Numbers may alſo be calculated.

XVII. If the Surface or the Paper where the Solar-Syſtem is drawn, Plate 3. Fig. 1. repreſents the Plain of the Ecliptic, or just the Earth's Path, we muſt imagine one Side of the Orbit of each Planet, to be elevated a little, and the other Side to be depreſs'd, ſo as to make an Angle with the Plain of the Ecliptic, as deſcrib'd §. 14. and cut the Ecliptic in two oppoſite Points, which are call'd, The *Nodes* of the Planets Orbits: The aſcending Node is that Point where the Planet croſſes the Ecliptic from the South to the North; its Place in the Ecliptic is ſet down in the Table; *e. g.* The aſcending Node of *Saturn*'s Orbit, is in 22 Degrees of the Sign *Cancer* ‡. &c.

Fig. 2. Plate 3.

XVIII. Every, Planet by its Motion round the Sun, deſcribes an Elipſis †, as A P D B, having the Sun in one Focus, s; and the Point A, which is at the greateſt Diſtance from the Sun, is call'd, The *Aphelion*: 'tis Place in the Eclipti*c*k is ſet down in the Table; for Inſtance, *Saturn* is at the greateſt Diſtance from the Sun, in 28 Degrees of *Sagittarius*; *Jupiter* in 9 Degrees of *Libra*; the *Earth* in 8 Degrees, 25 Minutes of *Cancer*, &c.

The Earth enters *Cancer* on the 10*th* of *June*; and therefore, on the 18 or 19 of *June*, it will be at the greateſt Diſtance from the Sun.

XIX. The

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‡ The Ecliptic is divided into 12 equal Parts, or Signs, which, Aſtronomers call by theſe Names, *viz.* *Aries*, *Taurus*, *Gemini*, *Cancer*, *Leo*, *Virgo*, *Libra*, *Scorpio*, *Sagittarius*, *Capricornus*, *Aquarius*, *Piſces*.

† An Elipſis is an Oval Figure, which is deſcrib'd upon a Plain, thus;

Fix the two Ends of a Thread, to the Points s f and with a Pin P, let it be ſtretch'd into the Direction s P f, then move the Pin forwards and backwards, keeping the Thread ſtretch'd, and it will diſcribe the Elipſis A p P D B. The Points s f, are call'd The *Foci*; The Line A D, the greater Axis; And the Point C, the Center.

A TABLE OF THE DIMENSIONS, MOTIONS, &c. OF THE PLANETS.

	Saturn	Jupiter	Mars	Earth	Venus	Mercury	Sun	Moon
Periods	29y 167d	11y 315d	1y 322d	365d 6h 9′	224d 17h	87d 23h	------	27d 7h 43′
Diurnal Revolutions	Not known	9h 56′	24h 40′	23h 56′	23h 0′	Not known	25d 6h	27d 7h 43′
Me. diſt. from Sun, Mil.	777000000	424000000	123000000	81000000	59000000	32000000	------	------
Diameters in Miles	93450	[illegible]	4875	7970	7906	4240	763000	2175
Proportion of Bulk	161	[illegible]	1/4	1	39/40	1/7	878000	1/50
Quantity of Matter	126	227	Not	1	Not		228700	1/40
Gravity on ye Surface	.92	[illegible]	known	1	known	------	24	.34
Inclination of ye Orbits	2° 30′	1° 20′	1° 52′	0° 0′	3° 24′	6° 54′	------	5° Variab.
Inclination of ye Axes	------	Very [illegible]	0° 0′	23° 29′	75° 0′	------	8° 0′	3° 10′
Proport. of Light & heat	1/100	1/28	3/7	1	1 3/4	6 1/2	4500	Variable
Velocities; Miles an hour	19000	25400	47240	58050	68040	92700	------	2300
Place of aſcending node	Can. 22°	Can. 8°	Tau. 19°	------	Gem. 15°	Ari. 15°	------	Variable
Place of ye Aphelion	Sag. 28°	Libr. 9°	Vir. 1°	Cap. 8° 25′	Aqu. 5°	Sag. 13°	------	Variable
Excentricities; Miles	44320000	20440000	10812000	1368600	606400	6634000	------	Variable
Mean Motion in ye Eclip.	0° 2′ 0″	0° 4′ 59″	0° 31′ 27″	0° 59′ 8″	1° 36′ 8″	4° 5′ 32″	------	13° 10′ 35″

Satel. of Saturn.	Periods round Saturn.	Diſtance from Saturn; Miles
1st	1d 21h 19′	202800
2	2 17 40	259700
3	4 12 27	362900
4	15 22 41	841000
5	79 22 0	2463000

Satel. of Jupiter	Periods round Jupiter	Diſtance from Jupiter; Miles
1st	1d 18h 28′	363600
2	3 13 17	580000
3	7 3 59	925000
4	16 18 52	1630000
From ye Earth to ye M		240000

Calculated from the moſt accurate

Obſervations by

John Booth

XIX. The next Line ſhews the Excentricities of the Orbits of the Planets in Miles; that is, the Diſtance s C from the Sun to the Center of the Orbit.

The Excentricities of their Orbits are ſo ſmall, that when they are delineated upon Paper, they appear to the Eye almoſt perfect Circles.

If the Excentricity be added to the mean Diſtance (ſhewn in the 3*d* Line from the Top of the Table) the Sum will be the greateſt Diſtance of the Planet from the Sun, and their Difference is the leaſt: Example, the Earth's meanDiſtance is 81000000 Miles. And the Excentricity of its Orbit 1368600 Miles, their Sum is 82368600, the greateſt Diſtance of the Earth from the Sun, and their Difference 79631400 the laſt Diſtance.

The Numbers in the 3 laſt Lines, are calculated from the Obſervations of Aſtronomers.

XX. The laſt Line ſhews the daily mean Motion in the Ecliptic; it is eaſily calculated, from the firſt Line in the Table; for every Planet deſcribes 360 Degrees, in the Time it goes round the Sun.

The little Columns at the Bottom of the Table, ſhew the Periods and Diſtance of *Saturn* and *Jupiter's* Satellites: They are plain from their Titles.

XXI. As the Eclipſes of the Sun and Moon are the moſt remarkable *Phænomena* of the heavenly Bodies, it may not be amiſs to ſhew the Cauſes of them, from what has been before explain'd.

Let A D C B, repreſent the Orbit of the Moon, S, the Sun, and a b c the Earth; when the Moon comes to A, directly behind the Earth, ſo that the Sun cannot ſhine upon her, ſhe will be Eclipſed: But, when ſhe comes out of the Shadow again, ſhe will begin to reflect the Sun's Rays, and appear to ſhine.

Whenever the Moon comes directly between the Earth and the Sun, as at C, her Shadow will fall upon the Earth, and ſo cauſe an Eclipſe of the Sun, on that Part of the Earth where the Shadow falls, as is evident by the Figure.

An Eclipſe of the Moon will be viſible all over the World, where the Moon is viſible; but an Eclipſe of the Sun will only be viſible where the Shadow happens to fall.

The Reaſon why there is not an Eclipſe every new and full Moon, is, Becauſe the Orbit of the Moon is inclin'd to the Plain of the Ecliptic; for Example, Suppoſe A B C D, repreſent the Orbit of the Moon; If we imagine the Part B A D to be elevated a little, and B C D to be depreſs'd; then, when the Moon comes to A, ſhe will not paſs thro' the ſhadow of the Earth, and therefore, not be eclips'd: And when ſhe comes to C, her Shadow will not fall upon the Earth, and conſequently there will be no Eclipſe of the Sun.

I have here added a Table of all the viſible Eclipſes of the Sun and Moon, to the Year 1800, which I have taken from the *Aſtronomical Rotula*, publiſh'd by the indefatigable and ingenious Mr. *Ferguſon*, whoſe Authority I can very ſafely rely on.

The firſt of the two Letters plac'd after the Days and Hours, ſhews whether the Eclipſe be in the Morning or Afternoon; and the ſecond, whether it be of the Sun or the Moon.

EXAMPLE.

In the Year 1743, *Oct.* 22 at 4 in the Morning, the Moon will be Eclipſed.

The

The TABLE.

1743	Oct.	22	4	M. M.
1744	Apr.	15	9	A. M.
1746	Aug.	19	12	A. M.
1747	Feb.	14	5	M. M.
1748	July	14	10	M. S
	July	28	11	A. M.
1749	Dec.	12.	8	A.M.
	Dec.	28	9	M. S.
1750	June	8	9	A. M.
	Dec.	2	6	M. M.
1751	May	29	2	M. M.
	Nov.	21	10	A. M.
1753	Apr.	6	6	A. M.
	Oct.	15	10	M. S.
1755	Mar.	16	12	A.M.
1757	Jan.	24	7	M. M.
	July	19	12	A. M.
1758	Jan.	13	6	M. M.
1760	May	18	10	A. M.
	June	2	7	M. S.
	Nov.	11	9	A. M.
1761	May	7	10	A. M.
1762	Apr.	27	4	M. M.
	Oct.	6	8	M. S.
	Oct.	21	9	A. M.
1763	Apr.	2	10	M. S.
1764	Mar.	6	11	A. M.
	Mar.	21	10	M. S.
1765	Mar.	10	2	A. S.
1766	Feb.	13	7	A M.
	July	25	7	A. S.
1767	Dec.	24	6	M. M.
1768	June	19	3	M. M.
1769	May	24	7	M. S.
	Dec.	2	6	M. M.
1770	Nov.	6	10	M. S.
1772	Sep.	30	6	A. M.
	Oct.	15	9	M. S.
1773	Sep.	19	7	A. M.
1774	Mar.	1	9	M. S.
1775	Aug.	15	5	M. S.
1776	July	19	12	A. M.
	Dec.	29	2	A. S.
1778	June	13	4	A. S.
1779	June	3	7	M. S.
	Nov.	12	7	A. M.
1782	Apr.	1	6	A. S.
1783	Mar.	7	8	A. M.
1787	June	4	5	A. S.
1788	May	24	7	M. S.
1790	Apr.	3	10	M. S.
	Apr.	17	12	A. M.
	Oct.	11	2	M. M.
1791	Mar.	23	2	A. S.
	Oct.	1	4	M. M
1792	Sept.	5	5	A. S.
1793	Feb.	14	10	A. M.
	Aug.	25	2	A. S.
1794	Jan.	20	10	M. S.
	Feb.	3	10	A. M.
1795	July	20	8	A. M.
1797	June	13	5	A. S.
	Nov.	7	4	A. S.
	Nov.	23	4	M. M.
1798	Nov.	12	7	M. M.
18[illegible]0	Sep.	20	11	A. M.

XXI. Comets are ſolid, compact, hard and durable Bodies, like the Planets, and move round the Sun in eliptical Orbits or Paths, having the Sun in one Focus, in the ſame Manner as the Planets, only their Orbits are much more excentric or oblong; and therefore, they will come very near the Sun on one Part of their Orbits, and go to a great Diſtance from it in another.

The Path of that Comet which appeard to us in the Years, 1531, 1607, and 1682, is repreſented by, A D E F Fig. 1. Plate 3. and L m n o p q repreſents the Path of that remarkable Comet which appear'd the ſame Year in which *Julius Cæſar* was ſlain; that is, 44 Years before CHRIST; and again in the Years 531, 1106, and 1680-1: And, Mr. *Whiſton* in his *Theory of the Earth*, makes it very probable, that the ſame Comet was in our Syſtem at the Time of *Noah*'s Flood.

Comets do not move in the Plain of the Ecliptic, or near it, as the Planets do; but their Orbits are variouſly inclin'd to it, and to one another, neither do they move all in one Direction, but ſome are direct, others retrograde in Motion.

When a Comet comes near that Part of the Syſtem, in which the Earth moves, it will appear to us as a great Blazing-Star; and the Sun beginning to heat it, it will emit a copious Steam, or Vapour, which will appear to us as a long Tail; and when it has gone by the Sun, for the ſame Reaſon, it will appear brighter, and with a longer Tail.

The great Comet of the Year 1680, Sir *Iſaac Newton* ſays, went ſo near the Sun, that it was heated 2000 times as much as red hot Iron, if it be poſſible any Body can retain ſuch an exceſſive Degree of Heat.

The ſame Comet goes at leaſt 11200 Millions of Miles from the Sun, and yet not above one 40*th* Part of the Diſtance to the fix'd Stars.

A Comet appear'd in the Beginning of the Year 1742, which mov'd almoſt in the ſame Manner, as that which was ſeen in the Year 1672.

For the Satisfaction of the curious, I have added the following Table from Dr. *Halley*'s Aſtronomy of Comets; ſhewing,

The Times when they were neareſt the Sun.				The leaſt Diſtance from the Sun.	The Periods.	When they are to appear again.
Years	Months	Days	Hours		Years	Years.
1580	Nov.	28	15	59628		
1585	Sep.	27	19	109358		
1590	Jan.	29	4	57661		
1596	July	31	20	51293		
1607	Oct.	16	4	58680	75.5	1758
1618	Oct.	29	12	37975		
1652	Nov.	2	16	84750		
1661	Jan.	16	24	44851	129	1789
1664	Nov.	24	12	102575		
1665	Apr.	14	5	10649		
1672	Feb.	20	8	69739	70	1812
1677	Apr.	26	0	28059		
1680	Dec.	8	0	612	575	2255
1682	Sep.	4	7	58328	75.5	1758
1683	July	3	3	56020		
1684	May	29	10	96015		
1686	Sep.	6	14	32500		
1698	Oct.	8	17	69129		
1727	Sep.	16	16	99865		

N. B. The leaſt Diſtance of the Comets from the Sun, is ſet down in ſuch Parts, as the middle Diſtance of the Earth from the Sun contains 100000.

I ſhall here add a ſhort Account of the Ebbing and Flowing of the Sea, as it has not been notic'd before.

This ſurprizing Reciprocation of the Sea, which ſufficiently puzzel'd the ableſt Philoſophers, in all Ages, till Sir *Iſaac Newton*'s Time, is now found to be only a particular Example, of a general Law of Nature; *viz.* that all Bodies attract all others; but, as it may not appear eaſily to every one, how this Action of Gravity, ſhould cauſe the Sea to Ebb and Flow twice in 24, or 25 Hours, I ſhall therefore explain it as well as I can, from the Principles before demonſtrated.

Fig. 3. Plate 3. Let A B Z D, repreſent the Earth, and imagine it to be void of Motion, and out of the Sphere of of Attraction of all other Bodies; then, if it be cover'd all over, to a conſiderable Depth with Water, the Surface thereof will form a perfect Globe, by the mutual Attraction of its Parts; but, if the Moon be at M, it will draw the Water into the oval Figure a b z d, for it attracts with a greater Force at a leſſer Diſtance; (by Chap. 1. ag. 5.) For Example, Suppoſe the Water at Z, on that Part of the Earth which is towards the Moon, be drawn forwards 7 Parts, from Z to z; then the Point C, being at a greater Diſtance from the Moon, will be drawn forward only 6 Parts, from C to ç; and the Point A, which is oppoſite to the Moon, will be drawn only 5 Parts, from A to a ‡.

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‡ If any one ſhould object againſt this Attraction of the Moon, by ſaying, That the Earth and Moon, according to this, would ſoon come together

In the ſame Manner we might examine how far any other Point, or Part of the Globe would be drawn by the Moon; as the Points B D, will be brought to b d, and conſequently, the Surface of the Water will become of the oval Figure a b z d.

Now as the Parts of the Earth are rigid, and ſtiff, they will not yield to the Difference of Attractions, but the Water giving way to the leaſt Force, or Difference of Forces, will therefore riſe into two Heaps, at a and z, and the dry Land will appear at b and d.

If the Earth be ſuppos'd to turn round its Axis, in the Direction a b z d, whenever any Part comes to z, or a, there will be high Water, and at b, and d, there will be low Water; therefore, there will be high Water, and low Water, twice in the Time that any Part of the Earth turns round from the Moon to the Moon again, that is in 24 Hours 48 Minutes.

The Sun will act upon the Waters, in the ſame Manner as the Moon; that is, ſo as to cauſe them ſwell on that Part of the Earth, which is towards the Sun, and on that Part which is oppoſite.

The Force of the Moon to move the Waters, is to that of the Sun almoſt as 5 to 1, *viz.* the Moon alone will make the Waters ſwell on 2 oppoſite Parts of the Earth about 10 Feet; the Sun alone, about 2 Feet.

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together, I anſwer, That the Earth and Moon both move round their Centre of Gravity, ſo the Earth may be continually drawn towards the Moon, that is deflected from the right Line in which it would otherways move, and yet not come nearer to the Moon; juſt in the ſame Manner, the Planets are continually drawn towards the Sun, by his Attraction, and yet they never come nearer him; and hence we might account for the Tides, from the Conſideration of Centrifugal Forces; but I ſhall omit that, eſpecially as I think the forgoing Method very eaſy, and natural.

This being the Theory of the Tides in general, let us ſee how it will agree with the Phænomena.

At new and full Moon, the Tides will riſe higher than at the Quadratures; as will be eaſily ſeen, thus; Fig. 4. Let a b c repreſent the Earth, S the Sun, and A D C B the Orbit of the Moon; when the Moon is at C, it will cauſe the Waters to riſe at o and b, 10 Feet; the Sun at S, for the ſame Reaſon, will make the Waters ſwell at o and b, 2 Feet; therefore, at thoſe two Parts the Water will ſwell 12 Feet.

Again, Suppoſe the Moon at A, it will ſtill make the Waters to riſe 10 Feet at o and b, and the Sun at S, will cauſe the Waters ſwell at o and b 2 Feet, conſequently the Waters will riſe at o and b 12 Feet, the ſame as when the Moon was at C. *Laſtly*, Suppoſe the Moon at B or D, it will cauſe the Waters ſwell at a and c 10 Feet, the Sun at s makes the Waters riſe at o and b 2 Feet; but by theſe two Forces there will not ariſe 4 Tides in a Day, for the Force of the Sun being ſmall in Compariſon of that of the Moon, will be deſtroy'd; and there will ariſe two Tides at a and c, 8 Feet each, by the Difference of Forces.

This would be the Height to which the Water would riſe, ſuppoſing the Earth all cover'd over, and if we make proper Allowance for the Situation of Places, Sands, Rocks, Iſlands, Straits, Currents, Winds, Land-Floods, *&c*, we can account for the Motions of the Water in moſt Parts of the World.

FINIS.

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Plate III